EFFECTS OF ORGANISMIC AND ENVIRONMENTAL FACTORS ON MANIPULATION OF CONTROLS IN A TWO-WHEELER DRIVING CONFIGURATION

A thesis submitted

in Partial Fulfilment of the Requirements

for the degree of

DOCTOR OF PHILOSOPHY

by

SYED ALIUL HASAN RIZVI

to the

INDUSTRIAL AND MANAGEMENT ENGINEERING PROGRAMME
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Dedicated to the memory of my father,

Janab S. Zafrul Hasan Rizvi,

an educationist and celebrated scholar of Arabic Literature,

who

alas! expired right at the time when experimentation

for this work was just to commence.

Till I breath my last shall I remain
indebted to him for whose obliging
nurturing and filial encouragement
I ought to have succumbed to the
onslaught of flinching failures and
flitting frustration!

CERTIFICATE

This is to certify that the work embodied in the thesis, 'Effects of Organismic and Environmental Factors on Manipulation of Controls in a Two-Wheeler Driving Configuration', by S.A.H. Rizvi has been carried out under our supervision and has not been submitted elsewhere for a degree or diploma.

N K Sharma

(N. K. Sharma)
Dept. of Humanities and
Social Sciences
Indian Institute of Technology
Kanpur 208016

(J. L. Batra)
Professor and Head
Industrial and Management En
Indian Institute of Technolo
Kanpur 208016

June, 1984

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SYNOPSIS

EFFECTS OF ORGANISMIC AND ENVIRONMENTAL FACTORS ON MANIPULATION OF CONTROLS IN A TWO-WHEELER DRIVING CONFIGURATION

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Driving situation presents a human-machine symbiosis where driver's survival is a function of how (s)he performs in a driving environment. The behavior of human-vehicle system is yet not fully understood and its interactions with the environment still remain unresolved. Various studies presented in this work were designed to provide answers to some of the basic issues related to the problem. In all, five studies were planned to investigate the effects of sex, age, motor-sidedness, acoustic noise and personality factors on human performance in a two-wheeler driving configuration.

A pool of subjects was selected through an analysis of the data related to organismic characteristics of the sample-population. From this pool sample-sets with appropriate subject-characteristics were selected for different experiments. Subject's responses were measured in terms of reaction times. Two independent variables, control position and motor load, having 2 and 4

levels respectively were present in all the five studies. The third factor that varied from study to study was sex (Study-1), age (Study-2), motor sidedness (Study-3), noise (Study-4) or personality factor (Study-5). A 2 (the varying factor) x 2 (control position) x 2 (motor load) within subject factorial design with repeated measures on the last two factors was employed in all the five investigations. The only study having unequal cells was the one related to personality so that, for this study an unweighted means type of ANOVA was performed.

Stimuli in 39 slides were projected on to a screen, in front of the subject, sitting on the vehicle in a thermally and acoustically sealed environmental chamber. Each slide contained atmost 4 items, consisting of either letters a, b, c, g and h representing accelerator, brake, clutch, gear and horn respectively or filler materials (triangle-, circle- and square-shape). Level of 'motor load' equalled the number of letters in a slide to which each subject responded by manipulating appropriate controls of the vehicle. Reaction times, under 'normal' and 'reversed' configuration of controls, were measured through a photo-circuit and a multichannel response measuring device (RMD). Current arrangement of controls on the vehicle represented 'normal' position and the one with right hand side controls brought to the left ('horn' remaining in its position) constituted the 'reversed' configuration of controls. Subjects performed under the stress of both speed and accuracy.

The first study investigated the effect of sex on driving. Ten males and ten females participated in the study. Results indicated that (1) There is no gender-effect on driving (2) Response time increases linearly with increase in'motor load' (3) 'Reversed' arrangement of controls is superior to the 'normal', particularly, under excessive'motor load' conditions. (4) Time-sharing ability is an important skill in driving.

In the second study, the effect of age on driving was investigated. Ten low-age males (16 to 25 years) and ten high-age males (35 to 45 years) participated in this study. Results indicated that (1) Age is a significant factor only at the extreme levels of motor load (2) 'Reversed' control configuration is more efficient than the 'normal' one under excessive levels of motor load. (3) Higher level of motor load results in increased response latency in drivers.

The third study investigated motor-sidedness effect on driving. Ten right-sided and ten left sided males, categorised by Annet's test, participated. Results indicated that (1) Laterality characteristics of humans do not effect their driving performance. (2) 'Reversed' configuration offers a more efficient version of control-position, particularly when there are extreme levels of motor-load. (3) Human response behavior in driving is closely linked with the levels of motor-load.

The fourth study examined effect of noise on human driving. Ten male subjects participated in this study. The experimental

chamber was furnished to simulate a real life driving acoustic environment by playing traffic noise, recorded during peak hours of traffic flow at one of the busiest crossings of Kanpur. After appropriate analysis and computations, the recorded noise converted into an equivalent sound pressure level of 88.11 dB, a value constituting the 'high level of noise' for the present study. The background noise of 62 dB represented 'low level of noise'. Results indicated that (1) Within the investigated range, noise has no effect on driving. (2) Contribution of noise to driving performance is not a function of control-positions. (3) Under the extreme conditions of motor load, 'reversed' arrangement is better than 'normal'. (4) Motor load has a direct effect on speed of human response.

The fifth study was undertaken to explore the effect of extraversion-introversion (E-I) on driving in light of the fact that majority of highway deaths (about 90%) can be attributed to incompetence of drivers and not to the vehicular or environmental defects. For the present study data gathered in the first experiment were restructured in terms of the E-I dimension using a standard E-I inventory. This provided 13 subjects as extraverts (7 males and 6 females) and 7 as introverts (3 males and 4 females) Results indicated that (1) Being an extraverted or an introverted does not matter in driving. (2) Marginal interiority (high RT) of introverts to extraverts in handling different levels of motor load is statistically non-significant. (3) 'Reversed' control

position is better than 'normal'. (4) Higher levels of motor load induce proportionately greater stress on humans.

The above findings lead to the following inferences/recommendations:

(1) Designers of two wheelers may consider in terms of two different control-configurations to bring in compatibility between the vehicle and motor load levels which drivers are likely to be subjected to.

(2) Time-sharing ability, representative of an important driving skill, needs to be further explored with maximum of experimental control.

(3) Little work has been carried out in training of high-age people on perceptuo-motor tasks like driving. Licensing bodies would have to be equipped with tests capable of identifying major problems of aging. Though the present work contributes significantly in this context to the already available store of knowledge on performance-behavior of elderly people, yet several issues pertaining to the problem remain still unsolved.

(4) In future experiments on motor-sidedness an attempt should be made to bring a match between stimuli-features and hemispheric specialisations. This would further add to the practical utility of experimental results.

(5) The finding that noise has no effect on human driving and suggestions available in literature that it has a detrimental,

neutral and beneficial effect on performance, necessitate a more concerted effort on the part of human factors engineers to explore this issue, in a more rigorous manner so as to make this debate somewhat more conclusive.

CHAPTER I

INTRODUCTION

Human performance engineering contributes not only to the betterment of human welfare but also augments the level of industrial production through an efficiently designed and developed man-machine system. Overall human-performance is a direct function of human's physical and mental capabilities as well as of the conditions of environment in which the task is being accomplished. Human factors engineering (ergonomics) evolves the basic principles and guidelines for system designers,who apply them to transform the hardware-related parameters into behavioral ones and vice-versa. Human factors engineers are required to play a role in such major phases of system-development as system planning, predesign, detail design, production, test and evaluation, and operations. Each phase of the system development, according to Meister (1982),'introduces behavioral questions that must be answered if the system is to be designed properly' (p. 119). Human-vehicle system presents one such system that poses a challenging task to the human factors engineers of today. Despite the fact that traffic engineering researches have been conducted for many years, the problem related to how human, vehicle and environment interact with each other remains still unresolved.

This state of affairs has led to exhorbitantly increasing number of accidents and deaths on roads. In India, for example, in the year 1977-78, 21,300 persons were killed and 110,000 persons injured in 121,000 highway accidents (Central Road Res. Instt., India, 1982). This amounts to an estimated total cost of accidents to be of the order of 0.3 % of the national income of the country.

Major responsibility to avert such road accidents, in future, goes to the shoulders of human factors engineers, particularly, in light of the reports that human component of human-vehicle system is directly responsible for about 85 to 90 % of the accidents that occur on road (Lewin, 1982). As regards the type of vehicles involved in these accidents, findings are that motorcycles account for an increasing number of deaths and injuries on roads (Oglesby and Hicks, 1982). In the United States of America, in 1977, 500,000 motor cycles were involved in accidents resulting in about 4,000 deaths and 400,000 injuries (Carraro, 1979). In India, a large number of motor cycles, scooters and other two-wheelers are there on the roads and safety of this unprotected category of fast moving traffic is exceedingly in doubt. In a driving task, in general, humans have to perform many motor actions almost simultaneously. How efficiently and successfully the individual tasks are accomplished would depend upon such aspects as characteristics of the driver, driving configuration (operations to be carried out) and the environmental conditions

of driving. Keeping these in view, an attempt was made through the various studies presented in this work to determine the effects of some organismic and environmental factors on manipulation of controls in a two-wheeler driving configuration. Among the organismic variables sex, age, motor-sidedness, and extraversion-introversion (E-I) dimension of personality were investigated, while the environmental factor explored was acoustic noise. In all the studies that were undertaken, response time constituted the basic measure of human performance. In addition, in all the studies an effort was made to establish that configuration of controls which would result in a more compatible form of human-vehicle system. In the course of investigations, human performance was studied under the stress of varying levels of motor load, while the levels selected were representative of those encountered in a real life driving environment.

The text of the thesis is organised into five chapters. Chapter II presents some major features of the ergonomics (human factors engineering) researches carried out by various investigators to study human performance with special reference to driving tasks. In Chapter III, problem and research methodology covering such aspects as experimental design of studies, subject-related information, details regarding stimulus-materials, the task, experimental set-up and general experimental procedure employed in all the investigations are presented. The next chapter, Chapter IV, forms the core of the thesis. In this

chapter effects of different organismic and environmental variables on operation-time of humans are studied. For each of the five studies undertaken the purpose, methodology, analysis, results, and discussion and conclusions are presented. A general discussion of these studies and conclusions based on their findings conclude Chapter IV. The last chapter of the work, Chapter V, contains a brief summary, the major conclusions of the work and recommendations in the form of scope for future research.

CHAPTER II

LITERATURE REVIEW

Driving a vehicle, in general, represents a task that requires division of attention. Many motor actions have to be performed almost simultaneously in a driving environment and the task-performance is closely dependent upon such aspects as organismic characteristics of the driver, driving configuration (operations to be performed), and the environmental conditions of driving. The purpose of this review is to present some major features of the existing ergonomics (human factors engineering) researches on human performance with particular reference to driving tasks. A systematic and well-focussed review of the material follows.

2.1 Response Time Studies

Human reaction time (RT) becomes an important measure of human performance wherever time-related events are a subject of research (Wierwille et al., 1983). Today, RT, the time taken to make a response following a stimulus (McCormick, 1976), is being identified as a global measure of human behavior (Fisher and Goldstein, 1983). Simple reaction-times and choice-reaction times (CRT) may be as fast as 0.12 to 0.33 seconds and 0.14 to 0.53 seconds respectively (Wargo et al.,1967), whereas general val of RT under laboratory settings are found to be of the order of

0.6 to 1 seconds (Fitts and Posner, 1967). Variables influencing RT-values are many (Fisher and Goldstein, 1983; Norman and Bobrow, 1975), while the two basic components of RT are decision time (DT) and movement time (MT) (Kerr, 1979). DT or initiation time represents time between stimulus - onset and response - initiation, while MT denotes time between initiation of movement response and its completion. Some other studies have suggested RT to have more than two components (Miller, 1983; Welford, 1981). Henry (1961) found that simple RT increased with the complexity of the movement to be initiated. This is the current thinking, too (Sheridon, 1981). Studies on RT versus average velocity, movement amplitude, target size, MT, and number of elements in response are also found in literature (Falkenberg and Newell, 1980; Quinn et al., 1980). Electromyographic and evoked potential studies have also been carried out to split RT into its various components (Vrtunski et al., 1983). In one of the most recent work Vrtunski and his associates (1983) have conducted an experiment where force-related aspects of CRT were considered as a measure of performance on the cognitive tasks.

In terms of models of RT, all the models which have been developed have consistently shown that RT is a linear function of information contained in stimulus-materials (Bricker, 1954; Crossman, 1953; Hicks, 1952; Hymen, 1953; Smith, 1977; Welford, 1981). The Hicks-Hymen law shows that intercept and slope of RT functions represent variables of an information

processing task (Johnson and Briggs, 1973; Keele, 1973; Smith, 1968). Stimulus identification and response selection durations depend upon the complexity of the task (Damos and Wickens, 1977), and noisy component of stimulus during responding gets filtered out until appropriate response has been selected (Broadbent, 1971; Keele, 1973). The intensity, modality and frequency of stimulus (Swink, 1966; Wierwille et al., 1983), muscle group of the responding member (Wargo et al., 1967), practice on the task (Mowbra and Rhodes, 1959) and, finally, stimulus response compatibility (Fitts and Posner, 1967), all have an influence on speed of RT.

In driving tasks, RT was found to be slower for persons who had committed higher number of accidents on road (Fergenson, 1971). Injection of path obstacles and crosswind disturbances (Weir-wille et al.,1983) have also a bearing on driving RT. From the literature it appears that in most of the previous studies on RT in driving, mainly braking RT has been considered (Johanssen and Rumar, 1971; Sivak and Olson, 1981; Synder, 1976). Mihal and Barret (1976) have indicated that perceptual style, perceptual information processing, and perceptual motor RTs are three sets of predictors in a driving environment. Some of these predictors have been applied in various studies (Barret et al., 1969; Gophor and Kahneman, 1971; Kahneman et al., 1973; Olson, 1974). Broadbent (1971) reported that perceptual motor RT is a good predictor of the effectiveness of driver's decision-making strategy.

To sum up, the available literature indicates that RTs of drivers under varying environmental conditions are yet not fully known (Wierwille et al., 1983). Most of the past researches remained confined to the study of RT function in the context of underlying processes or stages responsible for the delay between onset of stimuli and initiation of response. In driving tasks, it appears that RT studies can play a much larger role in future.

2.2 Time-Sharing Phenomenon

Time-sharing 'refers to situations in which the human being has two or more chores to which he has to alternate his attention' (McCormick, 1976; p. 49) and results, in general, in performance deterioration (Alluisi and Hall, 1963; Glucksburg, 1963; Weiner, 1975). The time-sharing ability is explained through the multiple resource theory of task-interference (Navon and Gophor, 1979; Norman and Bobrow 1975; Wickens et al., 1981; Wickens et al., 1983), according to which greater the level of task-interference larger would be the impairment in human-performance. Time-sharing skill also depends upon the task-characteristi (Wickens et al., 1981) and increase in response-competition (Wicken et al., 1983). Individual differences in time-sharing ability can be traced in terms of an individual's response making strategy (Damos and Wickens, 1980). Qualitatively, out of the two forms of information processing, viz., automatic and control it is the latter which humans usually adopt in concurrent task situations

(Hasher and Zacks, 1979; James, 1980; Logan, 1978; Schneider and Shiffrin, 1977). The parameters of Hicks-Hymen law serve as efficient tools in demonstrating the nature of task-interference (Briggs and Swanson, 1970; Broadbent and Gregory, 1965; Damos and Wickens, 1977). The upper limit of one's time-sharing skill has been referred to as 'residual attention' which is an important predictor of flight performance (Beringer et al., 1975; Damos, 1978). North and Gophor (1976) found dual-task measures to be good predictors of pilot-performance while Sverko et al., (1983) reported the concept of group time-sharing instead of general time-sharing.

In driving tasks, time-sharing phenomenon is exceedingly significant. Driver's time is shared by visual search and recognition activities, and the task of compensatory tracking (Stephens and Michaels, 1963). Studies on divided attention requiring two tasks to be performed concurrently by the drivers have shown significant decline in performance under the effects alcohal (Brewer and Sandow, 1980; Hamilton and Copeman, 1970; Maskowitz, 1973). In a traffic-sign perception task, loaded with such cognitive activities that closely resembled with those demanded in driving, Testin and Dewar (1981) found an impairment in driver's performance. From the literature, it appears that time-sharing phenomenon has not been extensively explored, particularly, with reference to the driving task.

To sum up, for some of the researchers, time sharing phenomenon is very well defined (Damos, 1978; Damos and Lintern, 1981; Sverko et al., 1983), while for others there is no evidence to support this phenomenon (Jennings and Chiles, 1977; North and Gophor, 1976; Waldeisen, 1974), whereas Damos et al. (1983) went even to the extent of suggesting to abondon this concept altogether. Burke et al. (1980), on the other hand, suggested that to provide relief from information overload to operators, multi modal presentation technique should be adopted in concurrent task situations. Sometimes, in divided attention type of tasks, symbolic cuing also reduces the cognitive load on humans (Chechile and Sadoski, 1983).

2.3 Gender Effect

Relatively fewer studies have been conducted to study the effect of sex on human performance. Studies that have appeared in the literature indicate that on a variety of tasks, males and females perform differently. Sex-related differences have been observed in terms of arm and leg strength (Hoster and Morrow, 1982), walking speed, energy expenditure and maximal aerobic power (Evans, 1980), and process of acclimation to hot-dry environment (Shapiro et al., 1980). In reaction time studies males outperform females at all levels of age (Maccoby and Jacklin, 1974), but in choic-reaction time tasks the two sexes do not differ in performance (Fairweather and Hult, 1972). In terms of the

decision-time (DT) and movement-time (MT) components of reaction time females are, respectively, found to be faster and slower than males. Further, DT and MT on addition nullify the effect of each other, resulting in a sex-independent mean reaction time (Landauer et al., 1980). Noting that DT is a cognitive delay and MT is a motoric delay (Welford, 1968), and also that males possess more of muscular power (Mc Guinness, 1976), it may be argued that females are as much superior to males in their cognitive competence as they are inferior in muscular power. This results in no effect of sex on CRT. Studies conducted by Sherman (1967), and Thompson et al. (1981) have indicated through their researches that males and females differ in their performance on spatial and cognitive tasks. In driving situations, Hagen (1975) found that males drive faster than females. Further, according to Hagen, males and females of low-age group differ in this respect much more than those in the high-age group. In connection with the accident-data on driving, the findings are that males commit more number of accidents on road than females and, therefore, are awarded more number of convictions (Berg, 1972). Probability of going too fast prior to an accident is higher for males, while that of committing more number of cognitive errors is higher in case of females (Storie, 1977). Bristow et al. (1982), however, did not agree with this finding and suggested that Storie might have found the difference in performance not because of sex but due to the differences between two sexes in terms of

their age or length of experience. A study by Wetherell (1981) assessed the efficacy of some auditory-vocal subsidiary tasks as measures of mental load on male and female drivers. He found that female-driving performance on subsidiary tasks interfered with their driving ability, while performance of males remained unaffected.

An overview of the available experimental studies on driving indicates that such characteristics as age, driving experience, violation of traffic rules etc. have been explored in the past. However, one important variable, viz., sex appears to have been overlooked in this area of research (Wetherell, 1981).

2.4 Age Effect

Despite the fact that anthropologically persons in the high-age group differ from those in the low-age group in terms of such characteristics as height, weight (Stoudt, 1981), stature (Tanner, 1962), sitting height, arm reach, and arm-span (Stoudt, 1981), 'there are almost no data at all available on the aged and the infirm' (Chapanis, 1974; p. 80). Existing data on psychological aging are not of much value to the human factors engineers (Fozard, 1981). Very few studies have appeared in the literature where effects of age on industrial tasks have been investigated (For example, Murrel and Edwards, 1963; Murrel and Humphries, 1978; Salthouse, 1982; Walker, 1964). Studies on the effects of age on such factors as illumination-

level needed for satisfactory visual performance (Fozard, 1981) audition (Corso, 1977), speed of response (Botwinick, 1970; Fozard, 1981; Welford, 1977), strength of icon and cerebral characteristics (Miller et al., 1981) have demonstrated that low-and high-age groups of persons constitute two distinct categories of human-population.

Studies on the driving tasks indicate 'that probability of accident involvement increases with increased age, beyond the age of approximately 40 or 50' (Salthouse, 1982; p. 12). In a driving task speed of response is a crucial factor. Salthouse (1982) found that high-age group people commit accidents due to their inability in maintaining a high rate of information-processing required of a modern driver. In a study on road-sign legibility during night-hours, Sivak and Olson (1981) found that driving performance of high-age people is considerably worse than that of low-age population.

Viewed as a whole, data available on aging are quite inadequate from the system-designers' view-point. The finding that age has no effect on industrial task-performance needs to be further explored, particularly, in light of the report that substantial number of workers leave their jobs at a relatively early age (Welford, 1958). Further, laboratory-based findings that do not agree with the observed behavior of low-and high-age

persons should be accepted only after these have been screened for subject - biasedness. Another important observation can be made in terms of specification of the word 'elderly', as cited in the literature. At present, purely arbitrary levels are being assigned to it (Stoudt, 1981), while 'chronological, physiological, and psychological age rarely coincide ' (Edhom, 1967; p. 218). Designating the word 'elderly' in a more scientific manner becomes more important when it is noted that problems of aging can best be conceptualised 'between the ages of 25 and 45, rather than at the period conventionally considered to represent the beginning of old age i.e. age of 65' (Salthouse, 1982; p. 10).

Persons in the future population are expected to have an average age higher than that of today's population (McFarland, 1976), and in the words of Fozard (1981), 'human factors engineerin in the years 2000 to 2025 will be dealing with many design problems different from those of today'(p. 8). Hence there is a need to take up extensive studies related to effect of age on human performance.

2.5 Laterality Effect

Though human beings are two sided organisms with a bilateral symmetry about vertical axis of the body, their paired limbs and sensory organs are functionally asymmetrical (Coren et al., 1982; Porac and Coren, 1978) on global basis (Coren and Porac, 1977). Reasons for this laterality have been suggested

in terms of biological (Porac et al., 1980), genetic and asymmetrical embryo developmental processes, all of these being based on the assumption of the presence of primary sidedness that dictates all the motor and sensory functions in a human being (Porac, et al., 1980). A very systematized work on laterality has been recently presented by Porac and Coren (1981) where relationship between laterality and sex, age, medical history, cognitive abilities, motor skills, social and cultural factors with reference to physiological and cerebral asymmetries has been demonstrated. Jones (1983), in his review on the work of Porac and Coren (1981), observed that small difference in right and left handers might have confounded with sex, particularly in light of the study of Tapley and Bryden (1977). Peters (1980) and Flowers (1975) studied the preferred-hand performance in right-and left-handed people. Based on hand, foot, eye and ear preferences Coren et al. (1982) found a relationship between stressful births and shift toward left-sidedness. For testing lateral preferences they used their own inventory. Annet (1970), too, developed a similar inventory. Left- and right-sided limbs are controlled, respectively, by right- and left-hemisphere, while visual and auditory information are bilaterally available to both the eyes and ears respectively. This suggests that human laterality is a multi-dimensional process (Porac et al., 198(Hand performance asymmetries depend upon such variables as task-complexity (Steingruber, 1975), sensory feedback (Flowers, 1975),

postural transitions (Kimura, 1977) and precision of force modulation (Peters, 1980). Effect of fatigue on hand performance assymmetry was studied by many (Annet, 1976; Barnsley and Rabinovitch, 1970; Peters and Durding, 1979) and findings have been in negative, implying thereby different brain organisations for the manual control between right- and left-sided people (Annet, 1972; Peters and Durding, 1979). Sex of an individual also has an effect on between- hand-differences in motor performance (Mc Keever and Van Deventer, 1977) and so is the case with the characteristic of input information required to be processed by the two hemispheres (Erikson and Schultz, 1978; Sergent, 1983). Studies on visual signal presentation to right- and left visual fields revealed that spatial or stimulus-response compatibility results in lesser response latencies of humans (Cotton et al., 1980; Katz, 1981). In terms of the sex differences, Kimura (1983) found that males show stronger functional asymmetry than females in intellectual and problem solving tasks. In visuo-spatial tasks males performed more accurately and efficiently than females (Harris, 1978; McGee, 1979), while females emitted more rotational hand movements than males when observed in a mental rotation task (McGlone,1981). Such findings become more valuable when viewed in light of the fact that females are superior to males in verbal task performance, whereas reverse is the case in spatial tasks (Healey, 1980; Walker, 1980).

To sum up, since the last two decades interest on differential functioning of hemispheres has evolved (Julliano, 1980) and, today, a large body of literature is available on the topic, there being about 1000 references cited in the work of Porac and Coren (1981) itself. In the area of ergonomics, it appears from the literature that laterality is yet not being considered as a variable of the study, while Wickens et al. (1981) suggested that through an arrangement of controls, where hemispheric task-congruency is kept in view, designers can achieve important time-sharing efficiency.

2.6 Noise Effect

The knowledge of how and why humans are affected by acoustic noise is presently of very limited nature (Johansson, 1983) and in - conclusive (Gawron, 1982). Human performance due to noise remains unaffected (Bachman, 1977; Cohen et al., 1980; Conard, 1973; Kryter, 1970; Wohlwill et al., 1976), gets improved (Poulton and Edwards, 1974; Slave, 1977), or is impaired (Eschenbrenner, 1971; Fiedler and Fiedler, 1975; Finkleman et al., 1979; Gulian, 1974; Gawron, 1982; Johansson, 1983; Simpson et al., 1974). Gawron (1982) summarised 58 studies on this topic by dividing them into three categories showing no effect of noise on human performance, facilitation and impairment due to it. This paper also provided a summary of noise intensities, its characteristics and exposure durations, nature of tasks, and performance measures, related to each of the studies reviewed.

Studies related to the effect of noise on humans have investigated such aspects as personality features (Di Scipio, 1971; Westman and Canter, 1976), vigilance performance (Eysenck, 1982; Mullin and Corcoran, 1977), choice-reaction time performance (Hartley and Carpenter, 1974), free-recall ability (Smith and Broadbent, 1981), tracking performance (Hartley, 1981), dual-task performance (Eysenck, 1982; Finkleman and Glass, 1970; Hockey, 1970), reading achievement (Cohen et al., 1973), annoyance due to air-traffic noise (Rylander et al., 1972), proof reading ability (Gulian, 1974; Weinstein, 1974; Weinstein, 1977), fatigue effects (Hartley, 1973), and standing equilibrium of humans (Harris, 1972). In addition to the above, some studies have also explored the effect of noise on such physiological measures of performance as heart rate, pulse amplitude and peripheral blood volumes (Kryter and Poza, 1980; Wheale and O'Shea, 1982). So far as the low intensity, continuous, and intermittent types of noises are concerned, these do not have a uniform effect on humans (Broadbent, 1971; Johansson, 1983; Poulton, 1976, 1978).

In driving environment most of the studies related to noise-effects have been of subjective nature (Kryter, 1970). Various studies on driving, reviewed by Kryter (1970), indicated that age and sex did not matter from the view point of noise-induced effects, but nationalistic difference did influence the tolerence of traffic noise. Driving performance was less

impaired under predictable noise than that under unpredictable noise (Finkleman and Glass, 1970). Drivers cater to the demands of immediate driving operation by employing a portion of their information processing capability and maintain the remaining capacity to meet other concurrent task demands that might arise during driving operation (Tversky, 1967). Broadbent (1957) suggested that with the additional demand drivers are left with a lesser spare capacity resulting in degradation in their driving performance.

To sum up, noise-effects on human performance can be detrimental, neutral and beneficial (Milosevic, 1983) implying thereby that 'performance under noisy conditions, is sometimes unaffected and sometimes improved or impaired'(Johansson, 1983; p. 275). Rotter (1982) observed that our knowledge about subjective influence of noise is very poor. Since noise has some after effects also (Glass and Singer, 1972), Moran and Loeb (1977) suggested to investigate the magnitude of such after-effects in concurrent task situations, too. Out of the 58 studies summarised by the review of Gawran (1982) it is important to note that none related to driving. This indicates how less has been done in the past to investigate the effect of noise on driving tasks. On one hand, noise might serve as a source of helpful cues to the drivers, while on the other hand a limit may come when presence of noise may give rise to an impairment in their driving performance.

2.7 Extraversion - Introversion Studies

Human personality 'consists of individual characteristics, in particular, the modes of thinking, feeling and behavior which in their organisation and patterning determine the individuals manner of interaction with his environment' (Ribeaux and Poppleton, 1978; p. 163). Many theories of personality have been developed in the past (For example, Cattell, 1965; Eysenck, 1953; Freud, 1940; Hartmann et al., 1971; Lindzey et al., 1971; Rogers, 1951). The extraversion-introversion (E-I) dimension of personality is a product of Eysenck's theory of personality. Characteristics associated with extraversion and introversion are well documented (Cattel, 1965; Mischel and Mischel, 1973; Smith, 1968). Some physiological differences between extraverts and introverts have also been reported in terms of cortical functions (Ribeaux and Poppleten, 1978), skin conductance and alpha activity (Eysenck, 1967), electroencephlographic features (Eysenck, 1982; Gale, 1973), and body temperature (Blake, 1967).

The E-I dimension has links with genetics and physiology closer than any other dimension of personality (Eysenck, 1981), and so is the case with the level of arousal. The effects of E-I dimension have been investigated by different researchers to cover up such aspects as affiliation and personal space (De Jullio and Duffy, 1977), group interactions and social skills (Daly, 1978) and occupational choice and aptitude (Blunt, 1978).

In industrial tasks, however, it appears that E-I dimension has not been widely considered. Few studies that have appeared in the literature have dealt with such aspects as level of boredom (Vest-wig, 1977), tapping skill (Eysenck, 1981), dual-task performance (Eysenck and Eysenck, 1979), learning behavior (Howarth, 1969), and vigilance performance (Harkins and Geen, 1975; Keister and McLaughlin, 1972).

In driving tasks, Fagerstrom and Lisper (1977) found extraverts to be poorer than introverts when studied over a period of four hours. This confirmed the Eysenck's arousal theory for introverted individuals (Wilson, 1981). Shaw and Sichel (1970) conducted a study on South African bus drivers and found that introverts were safer in driving than extraverted persons. Under the effect of alcohal, extraverts drove at much the same speed as before but they committed more errors in driving, while introverts bothered too much to compensate for the effect of alcohal, resultting in a marked decrement in their driving speed (e.g. Zeeman, 1976).

To conclude, human performance and E-I status appear to be closely linked with each other through the degree of arousal in the two categories of humans. The arousal theory and the fact that optimal level of arousal is inversely related to task-difficulty (Eysenck, 1982) lead to the prediction that extraverts

should be in a better position than introverts in coping with the complex tasks.

The review presented in the above subsections indicates certain directions of research,which are presented in the next chapter.

CHAPTER III

PROBLEM AND RESEARCH METHODOLOGY

The review of literature presented in the preceding chapter (Chapter II) suggested that effects of several organismic and environmental factors like sex, age, laterality, human personality, and acoustic noise on human behavior, in general, and on driving performance, in particular, are yet not fully understood. It, thus, leaves ample scope to investigate the effects of these organismic and environmental variables on human performance in a driving configuration. In this chapter the research problem has been formulated and the general methodology covering up such details as experimental design, subject's selection, stimuli-related features, the task employed, description of the experimental set-up, and, finally, the general procedure employed to carry out the present research is presented. Specific procedures related to the individual studies are covered up under each study in Chapter IV.

3.1 Problem Statement:

Driving situation presents a human-machine symbiosis where driver's survival is a function of how (s)he performs in a driving environment. The behavior of human-vehicle system is yet not fully understood and its interaction with the environment still remains unresolved. Various studies presented in this work were designed to provide answers to some of the basic issues related to the problem. In all, five studies were planned. The first study investigated the effect of sex on driving. In the second study the effect of age on driving performance was undertaken. The third study investigated the effect of motor-sidedness on driving. The fourth one examined effect of acoustic noise on human driving, whereas the fifth study was undertaken to explore the effect of extraversion-introversion, an important dimension of personality, on driving. In all the studies, first, response time constituted the basic measure of performance and, second, an attempt was made to determine, that control-configuration on two-wheelers, which would provide a higher level of human-vehicle compatibility. Further, in all the investigations, performance was studied under the different levels of motor load stress. The levels, selected,

were these encountered by drivers in real life situations. The terms control configuration and motor load are defined in section 3.4 below.

3.2 Experimental Design

In the studies, undertaken, responses were measured in terms of RT, which is treated as a dependent variable. RT was selected in light of the recommendations of previous researchers (e.g Wierwille et al., 1983). Two independent variables, control-configuration and motor-load having 2 and 4 levels respectively were present in all the five studies. The third factor that varied from study to study was sex (Study 1), age (Study 2), motor-sidedness (Study 3), noise (Study 4), or personality factor (Study 5). A 2 (the varying factor) x 2 (control position) x 4 (motor load) factorial design with repeated measures on the last two factors was employed in all the investigations. The only study having unequal cells was the one related to personality so that for this study an unweighted means type of analysis of variance was performed. For the repeated measures type of factorial design there was no software package available at the Computer Centre of IIT Kanpur and, therefore, to perform the analysis of variance a computer program in FORTRAN was specifically developed for this purpose.

3.3 Subjects

A pool of 209 potential subjects was selected as described below. The pool included both males and females and right-motor-sided as well as left-motor-sided persons in the age range of 16 y to 50 y. All of them were literate enough to understand the experimental task. It was also ensured that their availability does not pose any problem at the time they were needed for experimentation. To determine motor-sidedness, Annet's questionnaire (Annet, 1970) was administered to the sample population. This was a standard, self-administered questionnaire (Appendix A) related to handedness and footedness, and provided same information on motor-sidedness as that provided by behavioral tests of individuals (Porac and Coren, 1981; Raczkowski et al.,1974). Out of 500 questionnaires circulated among the IIT, Kanpur community members, 340 persons responded. Of these, 209 persons expressed their willingness to participate in the experiments. The sample - response status is presented in Table 3.1.

Table 3.1: Sample Response Status

Number of Persons				
Contacted	Responded	Declined to Participate	Agreed to Participate	
			Males	Females
500	340	131	163	46

Motor-sidedness was measured through the Preference Index (P.I.) (Annet, 1970) for each of the 209 cases. Information related to the sample-characteristics were processed through a COBOL program, developed for this purpose. Candidates having P.I. greater than 0.8 were considered as right-motor-sided, while those having a negative P.I. were accepted as left motor-sided people. This criterion was adopted due to the severe shortage of left motor-sided people in our Indian Society. Results of the computer output are summarised in Table 3.2.

Table 3.2: Results of the Sample Data Analysis

No. of Cases			Males	Females	Right Motor-Sided	Left Motor-Sided
Processed	Rejected	Accepted				
209	103	106	89	17	96	10

From this pool of subjects, sample-sets with appropriate subject-characteristics were selected for different experiments with the condition that none of the subjects participates in more than one experiments. All the participating subjects were paid at a rate of Rs. 5.00 per hour and there was no bonus scheme.

3.4 Stimuli:

Stimulus materials were presented to the subjects in the form of slides, each of which contained four squares of equal size. Each of these squares was filled up with either letters:

'a', 'b', 'c', 'g', 'h', or symbols: '△', 'O', '□'; letters standing respectively for accelerator, brake, clutch, gear, and horn of the two-wheeler while symbols were used as filler materials. The height and width of each letter/symbol when projected on the screen fitted in front of subject, at about 2 m distance, were 100 mm in size. Stimuli subtended a visual angle of 2.9 degrees of arc (calculated from the formula of Grahm (1965)), a satisfactory value according to Bailey's suggestions (Bailey, 1982). In all, there were 39 slides and their contents represented only those control-combinations of the vehicle which are usually needed to be operated in real life driving environment. These combinations included primary controls (those modulating motion of the vehicle i.e. throttle and brake) as well as the secondary controls (which do not modulate vehicle's motion i.e. gear, clutch and horn). Filler materials controlled the scanning time of operators. Contents of the slides were presented in a random order, the arrangement of the slides being indicated on the Observation-Sheet employed for recording RT data (Appendix B). All the slides had at least one of the letters,but no such condition was there for symbols. The stimuli were presented by a Kodak Carousel S Model projector (Philips, Holland). Brightness of stimuli were adjusted for their comfortable visibility.

Stimulus materials were designed to represent a prespecified level of motor load. Slides containing one, two, three, and

four out of the five letters constituted what has been specified, respectively, as one, two, three, and four level/levels of motor load.

3.5 Task

During experimentation subject sat on the vehicle with the two hands on the handle as one does in the driving position, and responded to the slides by operating the control(s) of the vehicle under instructions for both speed and accuracy. Subject was free to read the contents of the slides in whatever order (s)he liked in order to operate the control(s). Each subject participated in two separate experimental sessions, which involved either 'normal' or 'reversed' configuration of controls. Current arrangement of controls on the two-wheeler (accelerator: rotary type, right-hand (R-H) operated; brake-pedal: push-type, right-leg operated; clutch: lever type, left-hand operated; gear: rotary type, left-hand operated; horn: push-button type, left-hand operated) represented normal position (or configuration) and the one with R-H side controls brought to the left ('horn' remaining in its position) constituted the 'reversed' configuration of controls. Half of the subjects participated under 'normal' conditions of controls first, while for the other half the order of presentation of control-configurations was reversed.

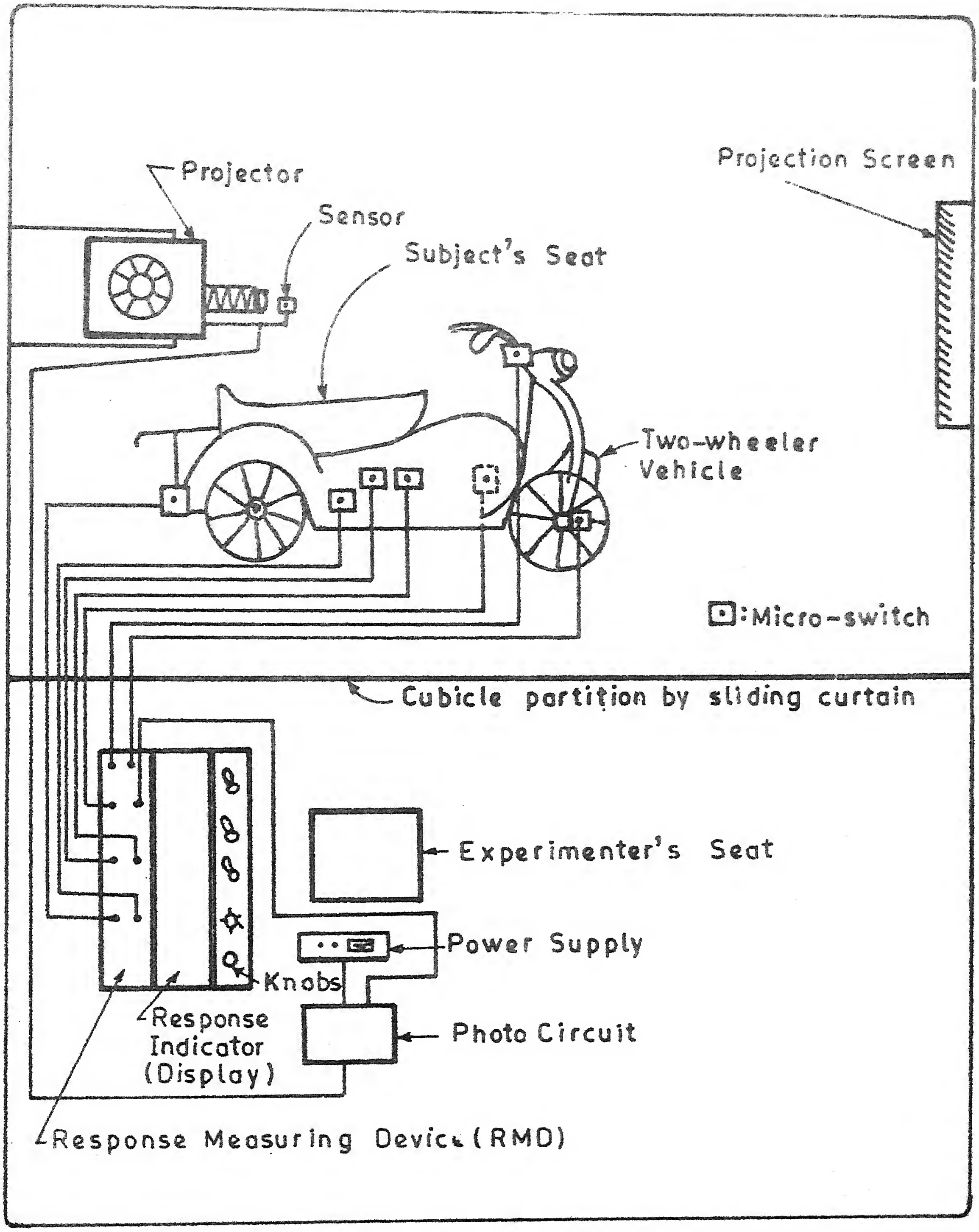

Figure 3.1. Schematic Diagram of Experimental Setup.

3.6 Experimental Set-up

A response measuring system was designed and developed indigeneously for recording on time scale those instants when stimulus was presented to a subject, and when controls were operated by him/her in response to the contents of the slide. Slides were projected on the screen using remote-control facility of the projector. To record the instant of slide-presentation, a photocircuit (Appendix C) was designed. As soon as the projector was switched on , light energy from its bulb energised the photo-transistor located at its focus. This, in turn, triggered the photo-circuit through which a signal was communicated to one of the channels of the response measuring device (RMD), which recorded and stored the desired instant of the event. Micro-switches were employed to trigger the different channels of the RMD for recording the instant when subject manipulated a control or a set of controls of the vehicle. The micro-switches were mechanically fitted to the control cables of the two-wheeler. The RMD was a 4 (event) x 8 (channel) time recording equipment with built in storage facilities. This was developed locally in the Industrial and Management Engineering Laboratory of the Institute. A block diagram representing the arrangement of various modules of RMD is shown in Appendix D.

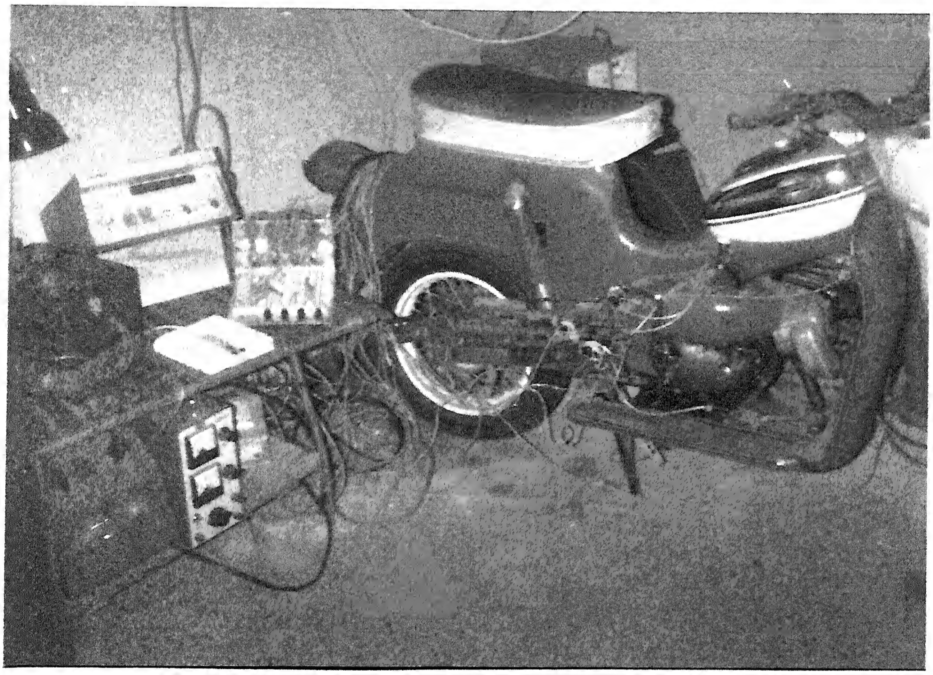

Figure 3.2. Photographic view of the experimental set-up.

All the experiments were performed in an environmental chamber of 3 m x 3 m x 2.5 m size. The chamber was fitted with a room air conditioner having a thermostatic control facility. For each experiment the temperature was maintained approximately at 23 degree celisius. Illumination in the chamber was relatively uniform with a minimum of shadows. When closed, the cubicle got acoustically sealed from the outside environment.

A schematic diagram showing the overall arrangement of experimental set-up and relative positions of the vehicle, screen and experimenter's seating position is presented in Figure 3.1, while Figure 3.2 presents a coloured photographic view (projector not shown) for the same.

3.7 General Experimental Procedure

Prior to the actual experimentation, a pilot study was undertaken. It helped in preplanning the details of experimental sessions and in checking the suitability of the Observation Sheet designed for collecting and processing the experimental data. For each study a sample of 20 (10 in study 4) subjects, each fulfilling the prespecified characteristics, was selected from the pool of potential subjects, given earlier. None of the subjects participated in more than one experiment.

The following preparatory steps were taken before the actual conduct of the experiment:

1. Each subject, selected for an experiment, was briefed about the objective of the experiment and the instructions to be followed (Appendix E), while performing the experimental task.

2. The subject-related characteristics, viz., age, height, weight, visual acuity and driving experience for each participating subject were recorded. Height and weight data were collected to give a completeness to the specification of the participating subjects. Visual acuity was tested using the standard Snellen's Chart.

3. A training session was organised for each subject to familiarize him/her with the various controls and their operations. At least one complete run of the experiment was undertaken for this purpose. The number of runs depended upon subject's capability to learn and comprehend the experiment. The purpose of this training was to reduce errors during the test trials.

After the subject had taken his/her seat on the vehicle and the instruments were in ready state, the following steps were involved, in the given order, for both the training as well as experimental sessions:

1. A verbal signal READY was given.
2. A slide was presented.
3. The subject responded by manipulating the appropriate control(s) of the vehicle.

4. RMD was reset for recording the next event (an event corresponds to Steps 1, 2, and 3).

These four steps constituted one cycle of operation. The cycle was repeated for each of the 39 slides. After every four cycles, however, the RMD was set in RCL mode to retrieve the stored data. If a wrong response was given to any slide, it was repeated toward the end of the experimental session. For each subject average experimentation period was one hour. Performance on 'normal' and 'reversed' control configurations was recorded at the same time of the day but, of course, on two different days. This helped in eliminating any effect that time of experimentation might have had on the subjects.

The above-described research methodology has been employed to carry out different experimental investigations presented in the next chapter (Chapter IV).

CHAPTER IV

EXPERIMENTAL INVESTIGATIONS

In this chapter effects of different organismic and environmental factors on operation time of human beings under the simulated conditions of driving are studied. For each of the five studies undertaken the purpose, methodology, results, and finally, discussion and conclusions are presented as described below.

4.1 Effect of Sex on Operation Time

Details of the experiment conducted to study the effect of sex on human driving performance are presented as follows.

4.11 Purpose

An over-view of the literature suggested that sex as a variable is not being considered in human factors engineering researches, whereas greater number of females today are coming out of their homes and joining even such non traditional jobs as those in police and defence services. As a result, like their male counter parts female office-goers, too, have to depend on not only the public transportation systems but, also on their own means of transportation. The two-wheeler type of vehicles are the most economical fast-moving form of the conveyance facility. With these considerations in view the present study

was designed to explore how males and females perform in a driving task with special reference to their ability in handling motor load imposed on them, while driving a two-wheeler. It was also investigated whether motor load handling efficiency, measured in terms of RT, gets influenced by a change in the vehicle's control-configuration from 'normal' to 'reversed'.

To state these objectives in statistical terms, following null hypotheses were structured:

1. Males and females behave in the same manner under the stress of varying levels of motor load imposed on them in a driving task.
2. 'Normal' and 'reversed' controls are equally efficient from the operator's view point.
3. Different levels of motor load impose equal amount of stress on human operators resulting in no difference in their driving performance.

4.12 Method

Twenty subjects (10 males and 10 females) participated in this study. Their age ranged from 16 y to 25 y, whereas the means of their heights and weights were 161.95 cm. and 48.85 kg. respectively. All the subjects had normal vision either with (n = 5), or without (n = 15) glasses.

The experimental procedure as outlined in Section 3.7 (Chapter III) was adopted for conducting the present experiment. All the experimental sessions were conducted in the morning between 0800 and 1000 hrs.

At the end of the experimental sessions subjects were requested to fill up a questionnaire (Appendix F) that related to the extraversion - introversion dimension of personality.

4.13 Results

On the overall, neglegibly small number of errors were committed by subjects in performing the experimental task. The results were, therefore, analysed in terms of the response time scores. To compute mean response times of a subject at different levels of motor load when (s)he performed the task under a given configuration of control, responses to all the 39 slides were considered. For the specific level of motor load, RT values were computed for different vehicular controls manipulated at this level of motor-load and, then, their arithmatic mean was obtained to get the required response score corresponding to the considered level of motor load. Arithmatic means rather than the slowest RTs were taken because of the randomness introduced into the design of the contents of the four squares of each slide. The individual and mean response scores and their SDs for both males and females under 'normal' and 'reversed' control positions (configurations) at different levels of motor load were obtained as presented in Appendix G. The overall means RTs for males and females under different combinations of treatment are reproduced in Table 4.11. From the RT values it is observed that response time increased with an increase in motor load,

irrespective of the sex of subjects.

Table 4.11: Mean RTs (in s) of males and females at different levels of motor load under normal and reversed control-configurations (Study 1).

Sex	Response Time Values (in s)							
	Normal Control Configuration				Reversed Control Configuration			
	Motor Load Levels				Motor Load Levels			
	1	2	3	4	1	2	3	4
Male	2.98	3.72	5.13	6.12	1.06	1.00	1.73	2.29
Female	3.02	4.37	5.99	6.58	1.08	0.96	1.85	2.16

A 2 (sex) x 2 (control position) x 4 (motor load) factorial design with repeated measures on the last two factors was employed for the analysis of variance. A preliminary test conducted on the ANOVA model through Bartlett's test (Winer, 1962) indicated that observed Chi-square (35.44) was higher than that tabulated (11.40) at $\alpha = 0.25$ (df = 9), which implied that interactions with subjects should not be dropped from the ANOVA model. Accordingly, F-ratios were computed. Results of the analysis of variance are summarised in Table 4.12.

Main effect of sex was not found to be statistically significant ($F < 1$) which implies that in a driving task response time was independent of the sex of the operator. Further, the

Table 4.12: Summary of the analysis of variance for RT data (Study 1).

Source of Variation	SS	df	MS	F
Between Subjects	69.13	19		
A (Sex)	2.34	1	2.34	0.63
Subject within Groups (Error 1)	66.79	18	3.71	
Within subjects	607.61	140		
B (Control position)	405.45	1	405.45	369.9^{+}
A x B	2.45	1	2.45	2.23
B x Subject within groups (Error 2)	19.77	18	1.10	
C (Motor load)	125.30	3	41.77	119.22^{+}
A x C	0.98	3	0.33	0.94
C x Subject within groups (Error 3)	18.92	54	0.35	
B x C	26.53	3	8.84	64.32^{+}
A x B x C	0.78	3	0.26	1.90
B x C x Subject within groups (Error 4)	7.42	54	0.14	

+ $p < 0.05$

factor sex did not interact significantly with control position ($F(1, 18) = 4.41$, NS) and motor load ($F < 1$), and so was the case with the second order interaction, viz., sex X control position x motor load ($F(3, 54) = 2.78$, NS). The significant interaction between control position and motor load ($F(3, 54) = 4.0$; $p < 0.05$) necessitated an analysis of the simple main effects. Results of

this analysis (Table 4.13) indicated that control position was statistically significant at all the four levels of motor load and so was the case with motor load under both the positions of control.

Table 4.13: Summary of the analysis of simple main effects (Study 1).

Source of variation	SS	df	MS	F
B (Control Position)				
At C1 (Motor load level 1)	37.33	1	37.33	98.83^{+}
At C2 (Motor load level 2)	94.13	1	94.13	249.23^{+}
At C3 (Motor load level 3)	129.96	1	129.96	344.11^{+}
At C4 (Motor load level 4)	170.57	1	170.57	451.63^{+}
Error Term : ERBC = 0.38				
C (Motor Load)				
At B1 (Control position: Normal)	130.54	3	43.51	632.05^{+}
At B2 (Control Position: Reversed)	21.29	3	7.10	103.23^{+}
Error Term : ERCB = 0.07				

+ $p < 0.05$

In the next phase of the analysis, mean response time scores of operators in terms of each of the primary and secondary controls of the vehicle were computed for different levels of motor load under 'normal' as well as 'reversed' configuration of

controls (Table 4.14). It was found that among the 'normal' and 'reversed' positions of controls, the 'reversed' offered a more efficient version of control-configuration. This trend was

Table 4.14: Mean RTs (in s) for operating controls at different levels of motor load under normal and reversed control - configurations (Study 1).

Vehicle-controls in Normal (N) and Reversed (R) positions	RT Values (in s)			
	Motor Load Levels			
	1	2	3	4
Accel. (N)	2.96	3.85	4.92	5.61
Accel. (R)	3.16	4.24	5.12	5.19
Brake (N)	2.89	4.00	4.85	6.47
Brake (R)	3.34	4.08	5.06	5.79
Clutch (N)	0.00	4.40	6.78	7.67
Clutch (R)	0.00	4.11	5.26	5.51
Gear (N)	0.00	0.00	6.28	5.80
Gear (R)	0.00	0.00	4.89	4.98
Horn (N)	3.16	3.90	4.28	5.34
Horn (R)	3.18	3.99	4.56	4.80

specially noticeable when motor load was high. Further, it was observed that an increase in motor load resulted in higher values of mean RT as expected. Relationship between response time and motor load (Table 4.15) was further explored through

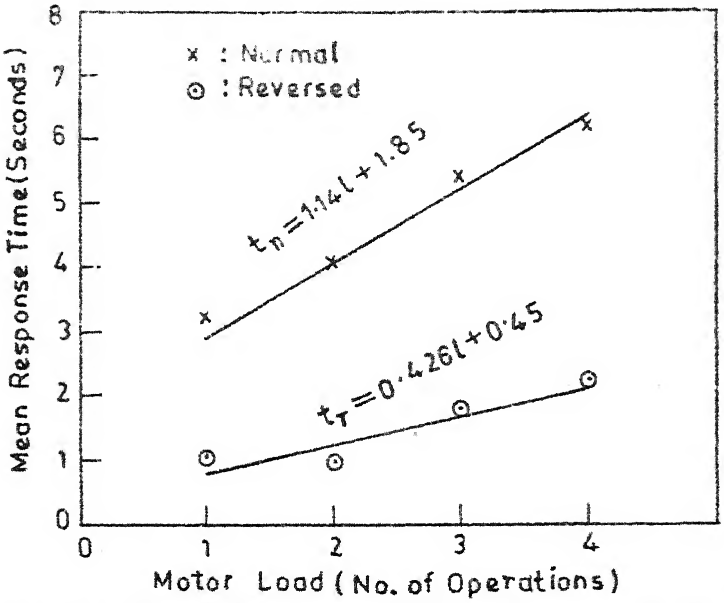

Figure 4·11. Responsetime as a function of motor load for 'normal' and 'reversed' positions of controls (study on sex).

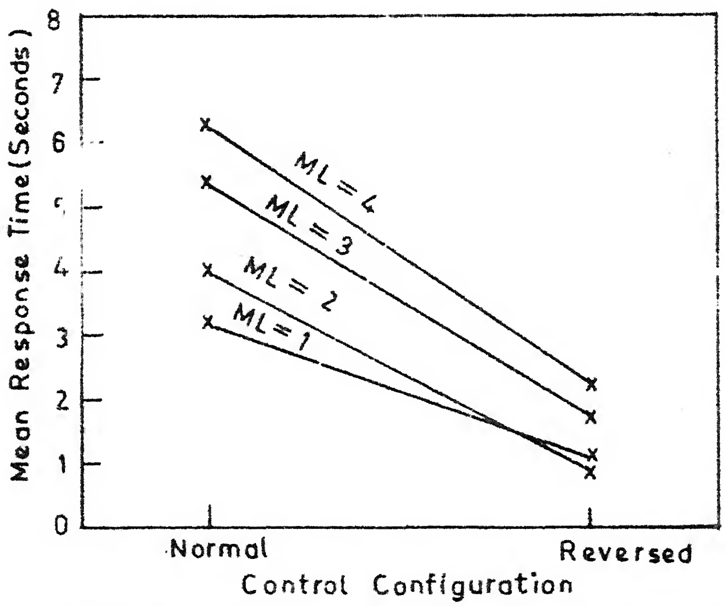

Figure 4·12. Response time under 'normal' and 'reversed' control configurations at different levels of motor load (ML) (study on sex).

the SCATTERGRAM routine of the SPSS computer package (Nie et al., 1975). On the basis of this analysis, curves of best fit were established as shown in Figure 4.11. The response time

Table 4.15: Mean RTs (in s) pooled over males and females at different levels of motor load under normal and reversed control-configurations (Study 1).

Configuration of controls	RT scores (in s) Motor Load Levels 1	2	3	4
Normal	3.0	4.05	5.40	5.85
Reversed	1.07	0.98	1.79	2.22

models indicated a linearly varying pattern of response scores with the motor load. Values of the correlation coefficient, R, R-squared, significance level, standard error of estimate, slope, and intercept parameters of the model were obtained as shown in Table 4.16.

Table 4.16: Statistics related to the best-fit curves of Figure 4.11.

Control-Position	Statistics					
	Correlation R	R-Squared	Significance Level	Standard Error of Estimate	Slope (in s)	Intercept (in s)
Normal	0.99793	0.99586	0.00207	0.11619	1.14	1.85
Reversed	0.92657	0.85853	0.07343	0.27342	0.426	0.45

Response time models for the two configurations of controls were obtained as follows:

Normal Control Position:

$$t_n = 1.14\,\ell + 1.85 \tag{4.11}$$

Reversed Control Position:

$$t_r = 0.426\,\ell + 0.45 \tag{4.12}$$

where t_n and t_r are RT - Scores (in s) for normal and reversed positions of controls respectively,

and ℓ is the level of motor load.

In the response time functions, for both the positions of controls, value of R (Table 4.16) was found to be quite high implying thereby a sound linear relationship between the variables RT and motor load. Proportions of explained variance in the RT functions, indicated by R-Squared value (Table 4.16) was also sufficiently high implying thereby a very high intensity of relationship between the two variables, the motor load and operator's response time score.

Response-time behavior of operators vis-a-vis 'normal' and 'reversed' configurations of controls are graphically illustrated in Figure 4.12. The curves in this figure reflect relative efficiency of the two control-configurations when operated at different levels of motor load.

4.14 Discussion and Conclusions

Results of the present study indicate that males and females are equally efficient in performing a driving task. The dependent variable or the measure of performance in this study was multiple-stimulus multiple-response type of reaction time. It was found that males and females did not differ significantly in handling the motor load imposed on them, while performing the task in a simulated environment of driving. This finding is supported by the results of Fairweather and Hult (1972), who found that adult males and females perform equally well in a choice reaction type of task. Studies of Krans in 1973, and Vanderkolk and Roscoe in 1973, as cited by Damos (1978) also led to similar conclusions. An explanation to the effect that the variable sex does not matter in visuospatial tasks, like driving, can be traced in terms of one of the recent findings that females are faster on decision times (DTs), while males are faster on movement times (MTs) (Landauer et al., 1980). Since males possess more of muscular power (McGuinness, 1976) it can be well argued that males must be superior to females on MT as was found by Landauer et al. also. On the other hand, females must be superior to males in their cognitive competency. As a result, differences in DT and MT components of CRT can be expected to be nullifying each other in the two cases of males and females, leading to an overall absence of sex-difference in human performance of the kind considered.

Another major finding of the present study is that positions of controls on a two-wheeler affect the driving performance of human beings and, hence, constitute an important factor in designing an efficient human-vehicle system. The study involved positions of the primary as well as secondary controls of the vehicle (as defined in Chapter III) as another independent variable. The position of these controls on a two-wheeler determines such operator dependent motoric features as limb to be used in operating a control, speed of operation, 'reach' features, and force and torque requirements. Whether a primary or secondary control is on right or on the left of the driver dictates how fast it can be operated and, perhaps, learnt too. Hand reach is one of the basic factors in design of vehicles (Simmonds, 1983), but how effective would this reach be would depend upon the hand to which the 'reach' refers to. It is from this ergonomics viewpoint that findings of the present study become all the more important. This calls for reviewing the existing designs of control-positions on the present day two-wheelers. Results of this study indicate that 'reversed' configuration of controls offers a more efficient version of vehicle-design and this leads to the next consideration: what specific controls out of the primary and secondary ones give rise to these findings? Is it the entire configuration of controls or just a few controls need to be relocated? Present findings indicate that any modification in the existing designs of two-wheelers would be basically a

function of motor load that drivers might encounter, while driving on road. It was found that at higher level of motor load the difference in performance under the two configurations of controls, namely, 'normal' and 'reversed' was more pronounced. Brake and accelerator positions were found to be more efficient in the 'normal' case, as suggested by the RT values presented in Table 4.14, but gear- and clutch-control positions proved to be more efficient in 'reversed' type of control-arrangement. Thus, it may be concluded that these are the secondary controls that have a positive impact on 'reversed' type of control position, while normal position of controls appears to be more efficient from the view point of the operation of primary controls. Therefore, for all kinds driving situations, involving different levels of motor load to be handled, no single configuration of controls out of the two being discussed over here may be recommended. Where complexities in driving task in terms of motor loading are likely to be more the 'reversed' arrangement appears to be a better proposition. But, for easy driving environment, from the motor loading view point, the 'normal' control type of vehicles might continue to have an edge.

While driving on road, the knowledge of distance at which a driver must operate a control or a set of controls is a very important factor from the traffic safety view point. In this context, values of the response latency presented in Table 4.14

might be of immense utility. These values suggest that at least 3 seconds must be reserved for drivers to make a response to the road-side environment in such simple situations where throttling, braking,and making horn type of activities are involved. For complex situations, however, the response latency values are much higher than a bare 3 seconds duration (7.67 seconds), and vary with the level of motor load that operators are required to process.

On the basis of the present study following conclusions are drawn:

1. There appears to be no gender effect in a driving task. This implies that sex does not seem to be a factor in the ergonomic design of driving vehicles, particularly, the two-wheelers.

2. Greater the level of motor load, higher is the stress induced in human operators, resulting in an impairment of their response making behavior. This observation of poorer response making pattern is best reflected by a linear RT model.

3. There appears to be a need to have a more critical appraisal of the existing positions of different controls on the two-wheeler type of vehicles. This study indicates that 'reversed' configuration of controls is more efficient than the 'normal' one.

4.2 Effect of Age on Operation Time

In the present experiment effect of the organismic variable, age, on response making speed of human beings in a driving configuration is studied. Details of this study are given below.

4.21 Purpose

The review of available literature on aging revealed that 'there are almost no data at all available on the aged and the infirm' (Chapanis, 1974; p. 80), and the studies that have investigated the aging problems did not yield much for the use of human factors engineers (Fozard, 1981). Keeping these facts in view, present study was designed to investigate if age is a significant factor in a driving task. Further, how it interacts with the motor load and configurations of vehicle-controls was also investigated. In view of the previous findings on aging it was expected that low and high age group people would demonstrate a difference in their driving performance. Since high age persons have been found to show poorer performance in studies involving road-sign processing and other information processing tasks in a driving environment, it was expected that high age people would, in this study, also show an inferior performance. Another objective of this study was to examine the efficacy of the 'normal' and 'reversed' type of control-configurations. Effect of motor load on speed of response was also investigated.

In light of the above objectives, following null hypotheses were structured:

1. Adults and old persons do not differ in their performance on a driving task.
2. 'Normal' and 'reversed' configurations of controls do not have any effect on driving performance.
3. Varying levels of motor load induce same amount of stress in human beings, while operating the driving controls on a two-wheeler.

4.22 Method

Twenty male right-sided subjects at two age levels, namely, low-and high - age level with 10 subjects in each category were selected from the pool of potential subjects after eliminating those who had participated in the previous study. Age of the low-age-level subjects ranged from 16 y to 25 y with mean at 20.9 y, while the same for high-age-level subjects ranged from 35 y to 45 y with mean at 41.5 y. These age levels were selected on the basis of some earlier suggestions (Salthouse, 1982). Mean height and weight of subjects were 166.45 cm and 56.3 kg. respectively. All the subjects had normal vision either with (n = 3) or without (n = 17) glasses. None had any driving experience.

Experimental procedure for the present study was the same as that adopted in the previous study. All the experimental sessions were conducted in the morning between 1030 and 1230 hours.

4.23 Results

As in the preceding study, subjects committed very few errors in this study too. Therefore, data were analysed in terms of response scores of subjects. RTs were computed by the method described in subsection 4.13 of this Chapter. The individual and mean response scores with their SDs for low-and high-age groups under different treatment combinations were computed as presented in Appendix H. From the mean RT values reproduced in Table 4.21 it is observed that response time for low as well as high age persons increases with an increase in motor load.

Table 4.21. Mean RTs (in s) of low and high-age operators at varying levels of motor load under normal and reversed control configurations (Study 2).

Age Level	Response Time Values (in s)							
	Normal Control Position				Reversed Control Position			
	Motor Load Levels				Motor Load Levels			
	1	2	3	4	1	2	3	4
Low	2.67	3.75	5.36	6.68	0.96	0.89	1.66	2.12
High	0.53	0.88	1.22	1.62	0.15	0.14	0.36	0.38

The analysis of variance was performed on the 2 (age) x 2 (control position) x 4 (motor load) factorial design with repeated measures on the last two factors. Bartlett's test

conducted on the ANOVA model revealed that observed Chi-square (68.05) was higher than that tabulated (11.40) at $\alpha = 0.25$ (df = 9), which implied that subject-interaction could not be dropped from the ANOVA model. Accordingly, F-ratios were computed. Results of the analysis of variance summarised in Table 4.22 indicate that main effects of control position ($F(1, 18) = 4.4$; $p < 0.05$) and motor load ($F(3, 54) = 2.77$; $p < 0.05$) were significant, while the main effect of age emerged to be statistically nonsignificant ($F < 1$). The interactions age x motor load ($F(3, 54) = 2.77$; $p < 0.05$) and control position x motor load ($F(3, 54) = 2.77$; $p < 0.05$) were also

Table 4.22. Summary of the analysis of variance for RT data (Study 2).

Source of Variation	SS	df	MS	F
Between Subjects	55.40	19		
A (Age)	0.55	1	0.55	0.18
Subject within groups (Error 1)	54.85	18	3.05	
Within Subjects	569.79	140		
B (Control position)	366.45	1	366.45	233.34+
A x B	1.36	1	1.36	0.86
B x subject within groups (Error 2)	28.27	18	1.57	
C (Motor load)	125.70	3	41.90	216.64+
A x C	2.69	3	0.90	4.63+
C x subjects within groups (Error 3)	10.44	54	0.19	
B x C	25.79	3	8.60	76.44+
A x B x C	3.02	3	1.01	8.95+
B x C x subjects within groups (Error 4)	6.07	54	0.11	

+ $p < 0.05$.

significant. The second order interaction age x control position x motor load, too, was significant ($F(3, 54 = 2.77$, $p < 0.05$). However, the first order interaction between age and control position was not found to be statistically significant ($F < 1$). Presence of second order interaction might have masked the main effect of age as well as its interaction with the control position. Therefore, it became necessary to undertake the tests of significance for simple - simple main effects and simple interaction effects (e.g. Kirk, 1968). Results of the simple-simple ANOVA summarised in Table 4.23 indicate that age is almost a non significant factor ($F < 1$), this being significant only at the fourth level of motor load ($F(1, 144) = 3.90$; $p < 0.05$) under the normal position of controls. However, the position of controls ($F(1, 72) = 3.98$) and motor load ($F(3, 108) = 2.72$) were again found to be significant at $p < 0.05$. The analysis revealed following interactions to be significant: age x control position ($F(1,72) = 3.98$) at the 4th level of motor load; age x motor load ($F(3, 108) = 2.72$) under 'normal' configuration of controls and control position x motor load ($F(3, 54) = 2.77$) at both the levels of age. All these tests were conducted at $p < 0.05$.

In the next phase of the analysis, response time values were computed at different levels of motor load in terms of each of the primary and secondary controls of the vehicle as presented in Table 4.24. As in the previous study, the results indicated

Table 4.23: Summary of the analysis of simple-simple effects.

Source of Variation	SS	F
A (Age) at:	0.36	F(1,144)
B1 x C1	0.36	0.5
B1 x C2	0.04	0.1
B1 x C3	1.38	2.0
B1 x C4	5.38	7.8+
B2 x C1	0.03	0.0
B2 x C2	0.08	0.1
B2 x C3	0.11	0.2
B2 x C4	0.23	0.3
Error term: ERABC = 0.69		
B (Control Position) at:		F(1,172)
A1 x C1	14.71	17.5+
A1 x C2	40.96	48.7+
A1 x C3	68.52	81.4+
A1 x C4	104.20	123.8+
A2 x C1	18.18	21.6+
A2 x C2	39.96	47.5+
A2 x C3	55.24	65.7+
A2 x C4	54.85	65.2+
Error term: ERBAC = 0.84		
C (Motor Load) at:		F(3, 108)
A1 x B1	93.64	612.25+
A1 x B2	10.44	68.28+
A2 x B1	41.59	271.92+
A2 x B2	11.53	75.40+
Error term: ERCAB = 0.15		
A x B at:		F(1, 72)
C1	0.20	0.41
C2	0.06	0.12
C3	0.75	1.57
C4	2.81	5.88+
Error term: ERABCR = 0.48		
A x C at:		F(3, 108)
B1	5.35	34.97+
B2	0.36	2.34
Error term: ERACBQ = 0.15		
B at:		F(3, 54)
A1++	22.17	197.14+
A2	6.64	59.03+
Error term : ERBCAP = 0.11		

+ $p < 0.05$

++ Numerals after A, B and C represent levels of factors A, B, and

that performance of operators got poorer with increase in the motor load irrespective of the type of control being manipulated and its configuration. It was also found that human response, while operating on occelerator, brake, and horn was more efficient for 'normal' control configuration so long as motor load was not

Table 4.24: Mean RTs (in s) for operating controls at different levels of motor load under normal and reversed control configurations (Study 2).

Vehicle-Controls in Normal (N) and Reversed (R) Positions	RT Scores (in s)			
	Motor Load Levels			
	1	2	3	4
Accel. (N)	2.56	3.53	4.99	5.40
Accel. (R)	2.99	4.00	4.63	5.23
Brake (N)	2.82	3.87	5.10	6.55
Brake (R)	2.92	3.75	4.70	6.03
Clutch (N)	0.00	4.12	5.94	7.20
Clutch (R)	0.00	3.59	4.37	5.34
Gear (N)	0.00	0.00	5.17	5.85
Gear (R)	0.00	0.00	4.18	4.89
Horn (N)	3.04	3.53	3.99	4.79
Horn (R)	2.96	3.57	4.10	4.72

excessive. At higher levels of motor load the 'reversed' configuration of controls was found to be more efficient. However, it was observed that clutch and gear were the controls which were always efficient in a 'reversed' type of control arrangement.

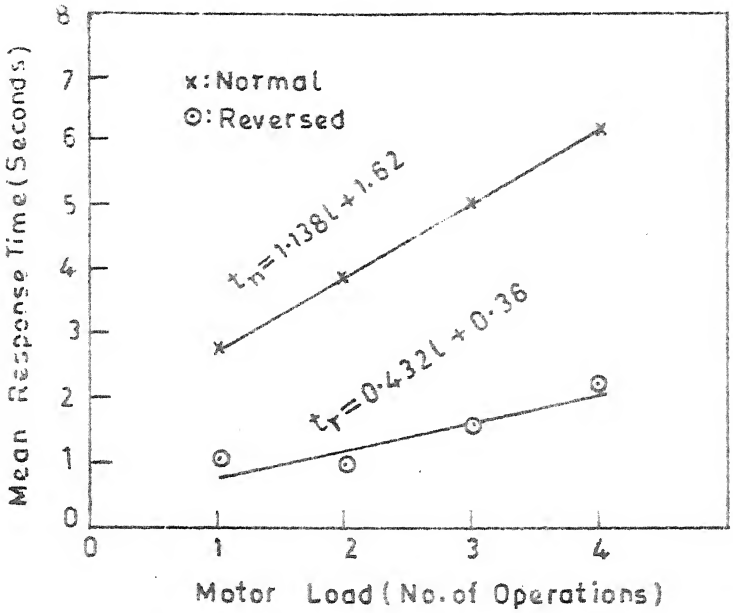

Figure 4·21. Response time as a function of motor load for 'normal' and 'reversed' positions of controls (study on age).

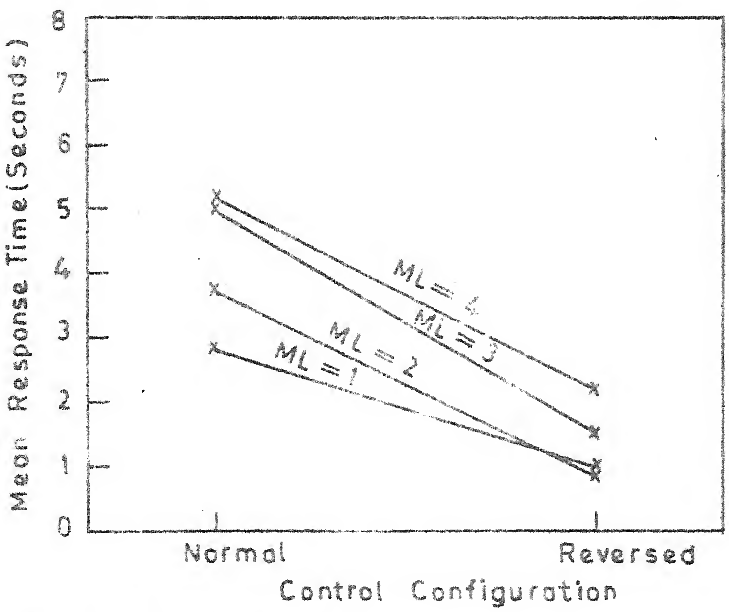

Figure 4·22. Response time under 'normal' and 'reversed' control configurations at different levels of motor load (ML) (study on age).

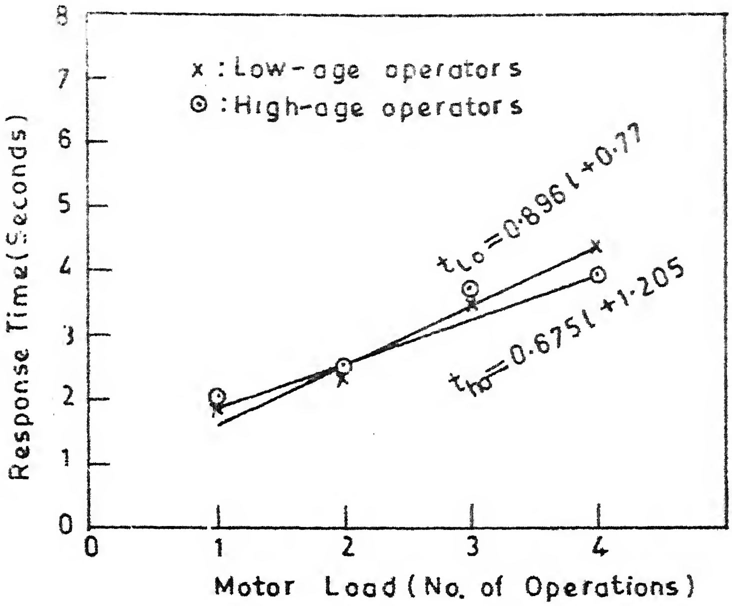

Figure 4·23. Response time as a function of motor-load for low-and high-age operators(study on age

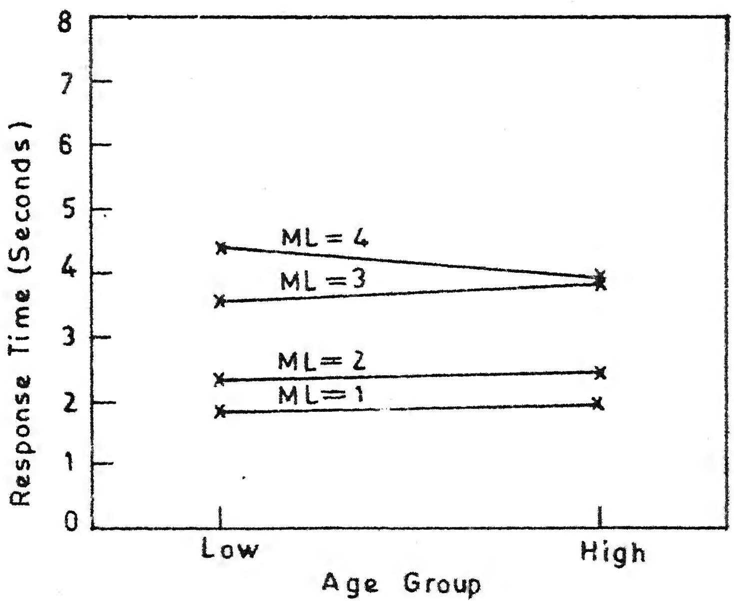

Figure 4·24. Response time of low- and high-age operators under different levels of motor load(ML) (study on age).

Relationship between response time and motor load was studied with reference to the two configurations of controls and the two levels of age by using the mean values of RT presented in Tables 4.25 and 4.26 respectively. RT functions of motor load for 'normal' and 'reversed' control positions (Figure 4.21) and the two age-levels of the subjects (Figure 4.23) were established by

Table 4.25: Mean RTs (in s) pooled over low-age and high-age operators at different levels of motor load under normal and reversed control configurations (Study 2).

Control Position	RT Scores (in s) Motor Load Levels			
	1	2	3	4
Normal	2.81	3.79	5.09	6.17
Reversed	1.00	0.95	1.58	2.23

Table 4.26: Mean RTs (in s) of low and high-age operators (pooled over normal and reversed control configurations) at different levels of motor load.

Operators Age	RT Scores (in s) Motor Load Levels			
	1	2	3	4
Low	1.81	2.32	3.51	4.40
High	1.99	2.42	3.71	3.99

employing the SCATTERGRAM routine of the SPSS software package. Response time models were developed on the basis of the statistics, slope and intercept provided by the computer-routine mentioned

above. A linearly varying pattern of RT versus motor load emerged under normal as well as reversed configuration of controls as shown by the RT models presented below.

For normal control position:

$$t_n = 1.138\, \ell + 1.62 \tag{4.21}$$

For reversed control position:

$$t_r = 0.432\, \ell + 0.36 \tag{4.22}$$

where, t_n, t_r, and ℓ are as defined in the preceding study.

On similar lines, models indicating relationship between RT and motor load for the low and high levels of age were also developed. Again a linear pattern was obtained. The models were as follows:

For low-age group:

$$t_{lo} = 0.896\, \ell + 0.7^{-} \tag{4.23}$$

For high-age group:

$$t_{ho} = 0.675\, \ell + 1.205 \tag{4.24}$$

where t_{lo} and t_{hi} are RTs for low- and high-age persons respectively and ℓ is the level of motor load.

Various statistics related to those models (Equations 4.21 through 4.24) were computed as presented in Table 4.27. It was found that the statistic R was considerably high in all the

Table 4.27: Statistics related to the best fit curves of Figures 4.21 and 4.23.

Factor	Statistics					
	Correlation (R)	R-Squared	Signified level	Standard Error of Estimate	Slope (in s)	Intercept (in s)
Normal Control Position	0.999	0.997	0.001	0.092	1.138	1.620
Reversed Control Position	0.931	0.866	0.069	0.269	0.432	0.360
Low Age Operators	0.989	0.979	0.010	0.205	0.896	0.770
High Age Operators	0.991	0.982	0.009	0.143	0.675	0.896

RT models implying thereby a very strong linear relationship between response speed and motor load. Further, high values of R-squared were also found in all these cases. This implies that the linear models fit very well to the sets of RT data indicating thereby a high intensity of relationship between RT scores and motor load.

Finally, response time of operators versus the two configurations of vehicular controls are plotted for each level of motor load as shown in Figure 4.22. This reflects relative efficiency of the two control configurations viz., 'normal' and 'reversed'. Similar curves are also drawn to highlight performance differences between low and high age groups of operators. These are presented in Figure 4.24.

4.24 Discussion and Conclusions

Results of the present study indicate that age-related effects in a driving task were almost non significant which implies that older and younger people were equally competent in their driving performance. At the extreme level of motor load, however, age did have an effect. When an operator was loaded with the fourth level of motor load response time for high age group was found to be significantly higher than that for the low age group. However, at the motor load levels lower than four, persons of the two age groups were not found to be significantly different. Further, at lower levels of motor load, response-speed for the low age group was found to be marginally high, though statistically non-significant. This marginal difference can be explained in terms of the findings of Botwinick (1970) who reported that 'in young adulthood speed of RT is often enhanced by a warning signal preceding the stimulus to respond, but this does not appear to be the case in old age'(p. 248-249). Thus, in the present study youngsters might have had an edge in making use of advance information in getting ready for making the required response. This, however, might not have induced a statistically significant difference in the driving performance of the two age-group people. The experimental evidence of Gottsdanker (1980) that all subjects irrespective of age differences benefit from advance probability information provides a support to the present

findings. Waugh et al. (1978) found a marginal increase in RT with age but, statistically, that too was nonsignificant. In their second study involving a binary choice RT similar results were reported. Studies by Fozard and Poon, cited by Fozard (1981), also could not find any age-related differences in terms of the error-scores or strategies, their subjects adopted in performing the assigned task. The task selected for the present study, viz., driving, is a complex coordinated sequence of perceptual and motor actions. Previous studies conducted on such perceptuo-motor tasks have not yielded 'an integrated description of the way in which age affects information processing capability' (Levison, 1981; p. 88). In light of these observations, this study seems to have contributed significantly to the present store of knowledge on human performance under the effect of aging.

The present finding related to superior performance of high age group at the fourth level of motor load contradicted Welford's generalisation (Welford, 1977) regarding relationship between slowing of response and age. He observed that old adults got slower in relation to youngsters when complexity of task was enhanced. This contradiction seems to be related to the over-generalisation (Levison, 1981) that Welford made, and possibly to the fact that the task structures in Welford's study and the present one were different. It has elsewhere been suggested

that by modifying a task structure age-related differences in speed of response could be reduced (Fozard, 1981).

To get further insight into the response-pattern of the two age groups, estimates of their dynamic processing capacities were computed. This capacity is usually measured by the processing rates of motor load and is taken as the reciprocal of the slope of the RT function (Salthouse, 1982). For the two age groups involved in this study these values of the estimates of dynamic processing capacities (For low age group: 1.11 per second; For high age group: 1.47 per second) were found to be significantly different. This conclusion is based on the finding that the interaction between age and motor load emerged to be significant. The efficiency of handling motor load for high-age people is high (Figure 4.24) but, over-all time taken by youngsters is found to be low (Figure 4.23). Possible reasons for this may be traced in terms of acquiring the information and then processing it for taking a decision to respond to the given stimulus. It has been reported in the literature that high-age people demonstrate their inability in maintaining a high rate of information processing (Salthouse, 1982). This results in longer RTs for high-age persons as is found in the present study.

So far as the present finding on configuration of controls in two-wheelers are concerned, this corroborates the results obtained in the previous study (sub-section 4.14). It was found

that 'normal' position of controls is faster than the 'reversed' type of control configuration. Statistically significant differences in performance of humans were obtained in the two cases of control positions. When viewed on individual basis both the configuration of controls showed similar pattern of response at different levels of motor load. A linear trend in response time behavior was obtained for both the positions of controls. Not only did the position of controls matter but also the interactive behavior between control-configurations and motor load was found to be statistically significant in deciding the speed of human response.

In the context of the effects of motor load, findings of this study indicate that irrespective of the levels of age and configurations of controls,humans are stressed (in terms of RT) in a linearly increasing manner with a rise in the level of motor load. For the two configurations of controls, significantly different values of slopes for the RT functions were obtained, implying thereby a strong interdependency between motor load and the two positions controls. Possible reasons for a decrement in performance with an increase in motor load and other similar issues related to motor loading of humans have been presented in Subsection 4.14 of this chapter.

Pattern of RT scores for individual controls presented in Table 4.24, indicates that operations of controls like accelerator,

brake, and horn when used in isolation from any other control (i.e. when motor load equals unity) lead to response latency values that remain almost uniform (Range: 2.56 - 3.04 s) in case of normal position of controls. This uniformity was even higher (Range: 2.92 - 2.99 s) in case of reversed configuration of controls. As motor load increased a different behavior of variation in response latency values was observed. This implies that in a complex environment of motor load handling, humans should be allowed to take longer in responding to the stimuli being attended. The implications of making these response latency values available to the system designers are discussed at length in the subsection 4.14 of the previous study.

Based on the above discussion, following conclusions are drawn:

1. Chronological age does not appear to be a significant factor in perceptuo-motor tasks like driving.
2. For excessive motor load, 'reversed' configuration of controls in two-wheelers is found to be a more efficient version of control arrangement than the 'normal' one. This may have implications for design - revisions in the existing two-wheelers.
3. Higher levels of motor load impose greater stress on human beings, which causes an increase in their response latency values.

4.3 Effect of Motor-Sidedness on Operation Time

In the present study human response making speed was investigated from the view point of motor-sidedness characteristic of human beings. Details of the study are as follows.

4.31 Purpose

The review of literature on human lateralisation (Chapter II) indicated that cerebral specialisation is a very distinct and well documented feature of human beings. It was found that laterality as a variable was not being considered in most of the human factors engineering studies. With these considerations in view present study was designed to bring out differences, if any, in performance of the right motor-sided and left motor-sided people with reference to their driving performance. Investigations were carried out to determine how the 'normal' and 'reversed' configurations of controls on two-wheelers affected the driving performance of left-sided and right-sided people. Further, the interaction between these two laterally different categories of people and their motor-load handling capacities with reference to the placement of controls on two-wheelers were also studied. These objectives stated in terms of statistical hypotheses were as follows.

1. People possessing right-motor-sidedness do not differ in performance from those with left motor-sidedness when tested under a driving configuration.

2. The 'normal' and 'reversed' types of control-arrangements in two-wheelers are equally effective for human driving.
3. In a driving task, human beings are equally stressed under different levels of motor-load.

4.32 Method

Ten right-sided and an equal number of left-sided males were selected from the pool of subjects (Chapter III) to participate in this study. Since there were only ten left-sided subjects in the pool, all of them were selected. The ten right-sided subjects, however, were selected randomly from the above mentioned pool, ignoring the ones who had taken part in the earlier studies. Age of the present sample of subjects ranged from 16 y to 25 y with the mean at 19.75 y. Sample's mean height and weight were 166 cm. and 54.1 kg. respectively. All the subjects were normal sighted either with (n = 3) or without (n = 17) glasses. All the experimental sessions were conducted in the after-noon between 1430 and 1700 hours. Other procedural details related to the present investigation were same as outlined in the previous two studies.

4.33 Results

Subjects committed almost neglegible errors in performing the experimental task. Therefore, results were analysed only in terms of response time scores. Computations for mean RTs were carried out in the manner similar to the one described in

the previous study. The individual and mean RT values alongwith their SDs for both right and left motor-sided people under the 'normal' and 'reversed' configurations of controls at different levels of motor load were computed as presented in Appendix I. From the mean values of RT reproduced in Table 4.31, it is clear that response time increases with an increase in motor load, irrespective of the motor sidedness of the operators. A 2 (motor-sidedness) x 2 (control position) x 4 (motor load) factorial design with repeated measures on the last two factors was employed to perform the analysis of variance on the observed

Table 4.31: Mean RTs (in s) of right and left motor-sided operators at different levels of motor load under normal and reversed control-configurations.

Motor-sidedness	Response time values (in s)							
	Normal Control Position				Reversed Control Position			
	Motor Load Levels				Motor Load Levels			
	1	2	3	4	1	2	3	4
Right	2.89	3.63	4.72	6.00	0.89	0.84	1.43	1.99
Left	3.02	3.91	5.73	6.49	1.46	0.92	1.64	2.17

data. The Bartlett's test conducted on the ANOVA model indicated that observed Chi-square (15.66) exceeded the tabulated value (11.40) at $\alpha = 0.25$ (df = 9), which implied that subject-interactions could not be dropped from the ANOVA model. Accordingly,

F-ratios were computed as presented in the ANOVA summary shown in Table 4.32.

Table 4.32: Summary of the analysis of variance for RT data (Study 3).

Source of Variation	SS	df	MS	F
Between Subjects	36.84	19		
A (Motor-Sidedness)	0.02	1	0.02	0.01
Subjects within groups (Error 1)	36.83	18	2.05	
Within Subjects	591.12	140		
B (Control Position)	399.80	1	399.80	473.60+
A x B	0.05	1	0.05	0.06
B x Subjects within groups (Error 2)	15.20	18	0.84	
C (Motor load)	119.69	3	39.90	154.26+
A x C	1.49	3	0.50	1.92
C x Subjects within groups (Error 3)	13.97	54	0.26	
B x C	28.01	3	9.36	40.48+
A x B x C	0.45	3	0.15	0.66
B x C x Subjects within groups (Error 4)	12.46	54	0.23	

+ $p < 0.05$

It was found that there was statistically no significant effect of motor-sidedness of subjects on their driving performance ($F < 1$). However, both the control-position ($F(1,18) = 4.41$; $p < 0.05$) and motor load ($F(3, 54) = 2.78$; $p < 0.05$) had a

significant effect on the RT scores. Moreover, the interaction between control configuration and motor load was also found to be statistically significant ($F(3, 54) = 2.78$; $p. < 0.05$), whereas other first order interactions, namely, motor sidedness x control position ($F < 1$) and motor sidedness x motor load ($F(3, 54) = 2.77$; NS) were found to be non-significant. Finally, the second order interaction, too, emerged to be non-significant ($F < 1$). Since control position x motor load interaction was significant the data were further analysed in terms of the simple main effects, rather than the overall main effects of the concerned variables as shown in Table 4.33. It was found that control-

Table 4.33: Summary of the analysis of simple main effects (Study 3).

Source of Variation	SS	df	MS	F
B (Control Position) at:				
C1 (motor load level 1)	37.64	1	37.64	98.00+
C2 (motor load level 2)	84.16	1	84.16	219.14+
C3 (motor load level 3)	132.13	1	132.13	344.06+
C4 (motor load level 4)	173.89	1	173.89	452.79+
Error Term: ERBC = 0.38				
C (Motor Load) at:				
B1 (Normal Control Position)	129.45	3	43.15	374.15+
B2 (Reversed Control Position)	18.25	3	6.08	52.75+
Error Term: ERCB = 0.12				

+ < 0.05

position was significant at all the four levels of motor load and so was the case for motor load that emerged to be significant under both the configurations of controls.

Response time scores of operators were also analysed in terms of each of the primary and secondary controls of the vehicle at varying levels of motor load under both the configurations of controls. Results of this analysis are presented in Table 4.34. In general, the pattern of response time variation was similar to the one obtained in the previous two studies (Subsections 4.13 and 4.23).

Table 4.34: Mean RTs (in s) for operating controls at different levels of motor load under normal and reversed control-configurations (Study 3).

Vehicle-Controls in Normal (N) and Reversed (R) positions	RT Scores (in s)			
	Motor Load Levels			
	1	2	3	4
Accel. (N)	2.96	3.58	5.36	5.53
Accel. (R)	3.03	3.61	4.37	4.86
Brake (N)	2.75	3.67	4.16	5.99
Brake (R)	3.15	3.71	4.33	5.71
Clutch (N)	0.00	3.85	6.55	5.53
Clutch (R)	0.00	3.40	4.29	5.05
Gear (N)	0.00	0.00	5.83	5.92
Gear (R)	0.00	0.00	4.31	4.77
Horn (N)	3.16	4.15	4.48	5.73
Horn (R)	3.06	3.50	3.98	4.53

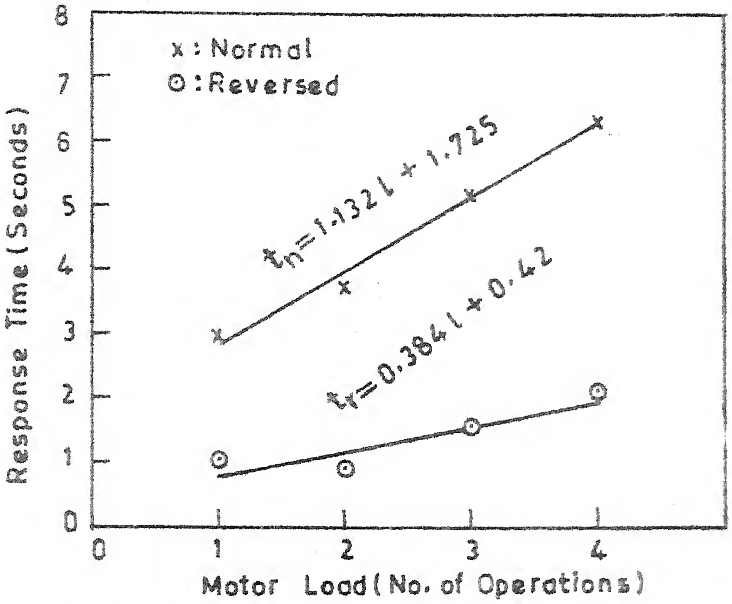

Figure 4·31. Response time as a function of motor load for 'normal' and 'reversed' positions of controls (study on laterality).

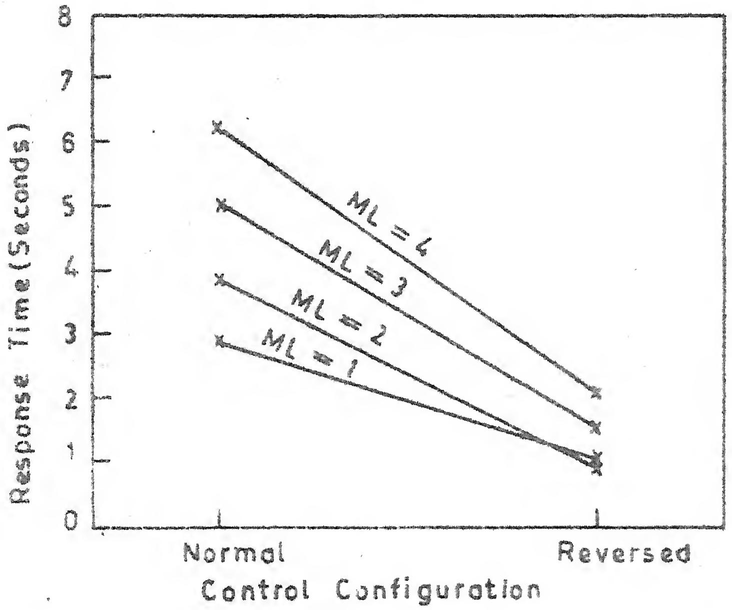

Figure 4·32. Response time under 'normal' and 'reversed' configurations of controls at different levels of motor load (ML) (study on laterality).

To study relationship between response time and motor load the mean RT values were computed for the operators irrespective of their motor-sidedness. Results are presented in Table 4.35. Based on these values of mean RTs, response time

Table 4.35: Mean RTs (in s) pooled over right and left motor-sided operators at different levels of motor load under normal and reversed control-configurations.

Control - Configurations	RT Scores (in s)			
	Motor Load Levels			
	1	2	3	4
Normal	2.95	3.80	5.17	6.27
Reversed	1.01	0.90	1.54	2.10

functions of motor load were plotted for 'normal' and 'reversed' configurations of controls as shown in Fig. 4.31. The SCATTERGRAM routine of the SPSS software package (Nie et al., 1975) was employed for this purpose. This revealed a linearly increasing pattern of RT for both the positions of controls, namely, 'normal' and 'reversed'. Following response time models were obtained:

For normal control configuration:

$$t_n = 1.132\ell + 1.725 \qquad (4.31)$$

For reversed control configuration:

$$t_r = 0.384\,\ell + 0.42 \tag{4.32}$$

where t_n, t_r and ℓ are same as defined in Equations 4.11 and 4.12 (Subsection 4.13).

Various statistics related to response time functions, shown in Fig. 4.31, were computed as presented in Table 4.36.

Table 4.36: Statistics related to the best fit curves of Fig. 4.31.

Control Position	Statistics					
	Correlation R	R-Squared	Significance Level	Standard Error of Estimate	Slope (in s)	Intercept (in s)
Normal	0.907	0.824	0.0925	0.281	0.384	0.42
Reversed	0.994	0.988	0.006	0.194	1.132	1.725

It was found that R-values for the obtained RT models (Equations 4.31 and 4.32) were high for both the positions of controls. This implies a strong linear association between motor load and the response time of operators. The proportion of explained variance, indicated by the R-squared value (Table 4.36) is also found to be quite high, this being relatively higher for the normal configuration of controls, demonstrating thereby a high degree of relationship between the two variables, namely, motor load and response time of operators.

In the final phase of the analysis, response time of operators vis-a-vis control-configuration at each level of motor load was studied as illustrated through the curves obtained in Figure 4.32. This reflects relative efficiency of the two configurations of controls, viz., 'normal' and 'reversed' under varying levels of motor load.

4.34 Discussion and Conclusions

An important finding of the present study is that human laterality being measured here in terms of motor-sidedness does not appear to have a significant effect on response making speed of human beings. In light of the previous studies related to laterality-effects on sensori-motor coordination (Daniels, 1981; Laundauer et.al., 1980; Porac and Coren, 1981) it was expected that present study would also indicate differences in driving performance of the right and left motor-sided people. Results, however, were contrary to this expectation. In view of the findings of this study, manufacturers of two-wheelers need not bother to develop two different types of vehicles for the two apparently distinct categories of people, viz., right and left motor sided individuals. The finding that motor-sidedness does not have an influence on driving performance of human beings gets support from the work of Kelso et al. (1979), although their experimental task did not involve a driving like response situation. Kelso et al. conducted a study in which

subjects were required to move the fingers from home-keys to targets in such a manner that all the movements were lateral in nature. They reported no significant hand differences in the reaction time index. Moreover, their subjects initiated the hand movements in paired conditions almost simultaneously. The driving task, employed in this study, also happens to be a task based on the coordination of two handed movements. Following Kelso et al. it may be assumed in the present study that, while operating the controls of the vehicle the movements of the two hands of subjects were such that there was no relative delay on the part of either of the two hands. In other words, the two hands may be assumed to have initiated the task assigned to them virtually simultaneously. This could have possibly led to the absence of motor sidedness effect in human driving as revealed by the present study. The study conducted by Borod et al. (1984) also provides support to the present finding. They reported that on a wide range of performance measures of laterality, the left handers and right handers did not differ significantly.

The findings of this study may be generalised to suggest that all those tasks that demand coordination of the two hands, laterality factor does not play a significant role. This implies that simply being right-handed or left-handed does not reflect anything related to the coordination capabilities of the two hands of an individual. Rather, it indicates a bare fact of

the hand preferences and not of the hemispheric activities.. There are many individuals with mixed handedness, and this provides an evidence that capacities of the two cerebral hemispheres are adequate enough when viewed from the manual skill view-point (Annet, 1970). This point of view gets support from the finding that many persons are forced to use their non-preferred hand in such skills as playing of musical instruments (Oldfield, 1969) that need fine motor control of both the hands. The present finding that present day two-wheelers supposedly designed for right handers are equally fit for the left handers also does not appear to be strange when it is known that left handers are not at a disadvantage when playing at instruments like piano that demands faster or delicate motoric performance of the right hands of humans (Walker, 1980).

As regards the position of controls, the reversed arrangement is found to be more efficient for subjects performing the driving task, particularly, in an environment of excessively high motor load. Reasons for this kind of driving behavior have already been discussed in Subsections 4.14 and 4.24 of this chapter.

The non-significant interaction between motor sidedness and control-position indicates that laterality has no effect on control-configurations implying thereby a uniform effect of control-position on driving performance of right and left motor-sided populations.

Another major finding of this study is that as the level of motor load increases there is a continuous deterioration in the response making speed of humans. Possible explanations to this effect have been presented in Subsections 4.14 and 4.24 of this chapter.

To sum up, the following conclusions are drawn from the present study:

1. Driving performance of humans is not affected by their laterality characteristics. This implies that the two-wheelers being designed today are equally efficient for right as well as left motor-sided people.

2. Position of controls on the present-day two-wheelers are required to be further investigated from the human-compatibility view-point. Present research indicates that 'reversed' configuration of controls offers a more efficient version of control position, particularly, when human beings encounter a complex environment of motor loading.

3. Level of motor load is a highly significant factor in deciding the overall performance of humans in a driving configuration. Present findings indicate that driving performance gets impaired with an increase in the level of motor load.

4.4 Effect of Noise on Operation Time

The preceding three studies related to investigations that involved organismic characteristics such as sex, age and motor-sidedness. Present study explores the effect of one of the most important factors of environment, viz., acoustic noise on human driving performance. Details pertaining to this study are as follows.

4.41 Purpose

The review of literature (Chapter II) suggested that noise-effect on human performance could be detrimental, neutral or beneficial. In the context of driving, it was pointed out there that traffic noise may either present helpful cues to the drivers or may lead to an impairment in their driving performance. In light of the abovementioned contradictory findings in the literature, on one hand, and the importance of study of noise in a driving configuration on the other, the present study was designed to investigate the effect of acoustic noise on human performance in a driving task. The operations involved in the experimental task were the same as in the earlier studies reported in this chapter. The study aimed at investigating if there is a differential in the response making speed of humans under the influence of noise when they operated the two-wheelers under two different configurations of controls at varying levels of motor load. When stated in statistical terms following null hypotheses were structured.

1. In a driving task human performance is not affected due to the presence of noise.
2. 'Normal' and 'reversed' configurations of vehicular controls are equally efficient under the influence of different levels of noise.
3. Driving response time of humans is not affected due to a variation in the level of motor load.

4.42 Method

Ten right handed males selected from the pool of potential subjects (Chapter III) participated in the present study. Their mean age, height and weight measured at 24.6 y, 168.2 cm. and 58.1 kg. respectively. All the subjects had normal vision either with (n = 9) or without (n = 1) glasses. None had any driving experience. The experiment was conducted on all the subjects at a fixed time of the day i.e. between 0900 and 1200 hours.

The experimental chamber was furnished to simulate a real life acoustic environment by playing pre-recorded traffic noise inside the chamber at appropriate dB levels. The subject performed the task under the influence of acoustic noise. Recording of traffic noise was done at Bara Chauraha Crossing, one of the busiest crossings of Kanpur City during peak hours of the traffic flow. A high fidality cassette tape recorder (Nelco make) was used for this purpose. The recorded noise that fluctuated with time of the day was converted into equivalent sound pressure

level (ESPL) using the technique employed by Lipscomb and Taylor (1978). The ESPL provides an average level of noise over a prespecified period of time, which was 45 minutes for the present study. This length of time was estimated on the basis of the average run time of the experimental task required in the precedint three studies. The dB level of the recorded noise was measured by using a sound level (SL) meter (Model 1551-C of General Radios, USA). To compute ESPL, microphone of the SL meter was positioned approximately at the ear level in the centre of the subject's seat. Volume control of the tape recorder was adjusted to produce a comfortable level of listening. Sound intensity level, once set, was maintained throughout the experiment. Computational steps involved in converting the dB level of recorded sound into ESPL are outlined in Table 4.41.

Table 4.41. Conversion of recorded sound into equivalent sound pressure level (ESPL).

SL Meter Reading for SPL (in dBA)	Counts per dBA (interval:30s)	Midpoint of SPL (in dBA)	Counts per interval	Fraction of total time	$10^{(L_i/10)}$	$(x_i.d)$
a	b	L_i	C	$x_i = C \div (\Sigma b)$	d	
85 86	2 7	85.5	9	0.10	3.55×10^8	0.355×10^8
87 88	19 30	87.5	49	0.55	5.62×10^8	3.09×10^8
89 90	23 6	89.5	29	0.32	8.91×10^8	2.85×10^8
91 92	2 1	91.5	3	0.03	14.1×10^8	0.423×10^8
	$\Sigma b = 90$					$\Sigma(x_i.d) = 6.718 \times 10^8$

Equivalent sound pressure level (ESPL)

$$= 10 \log_{10} (\Sigma x_i (10)^{(L_i/10)}) = 88.3 \text{ dB}$$

The computed equivalent sound pressure level of 88.3 dB constituted the high level of noise, while the background noise measured at 62 dB was taken as low level of noise. Performance of subject while operating on two respective configurations of controls was studied under the influence of both the levels of noise. Half of the subjects were exposed to the high noise treatment first, while to the remaining half, low-noise treatment was administered first.

Other precedural details were the same as outlined in Subsection 3.4 of the 3rd Chapter.

4.43 Results

Subjects committed neglegibly small number of errors in performing the experimental task. Therefore, results were analysed only in terms of RT data. The procedure for computing mean values of RT at different levels of motor load was same as given earlier (Subsection 4.13). Individual and mean RT scores (alongwith their SDs) of subjects under the stress of low as well as high levels of noise for 'normal' and 'reversed' configurations of controls at varying levels of motor load were computed as shown in Appendix J. From the mean RT values reproduced in Table 4.42 it was found that RTs increased with increase in motor load. For performing the analysis of variance a 2 (noise level) x 2 (control position) x 4 (motor load) factorial design with repeated measures on the last two factors was employed. Bartlett's test on the ANOVA model indicated that observed

Table 4.42: Mean RTs (in s) of subjects operating vehicular controls under the influence of low and high levels of noise at different levels of motor load under normal and reversed control-configurations.

Level of Noise	Response time values (in s)							
	Normal Control Position				Reversed Control Position			
	Motor load levels				Motor load levels			
	1	2	3	4	1	2	3	4
Low	2.87	3.82	5.08	6.45	0.99	1.04	1.67	2.50
High	2.76	3.61	4.87	5.93	0.97	0.83	1.60	2.32

Table 4.43: Summary of the analysis of variance of RT data (Study 4).

Source of Variation	SS	df	MS	F
Between Subjects	38.10	19	2.01	
A (Noise)	1.67	1	1.67	0.82
Subject within groups (Error 1)	36.43	18	2.02	
Within Subjects	546.61	140	3.90	
B (control position)	347.22	1	347.22	253.38+
A x B	0.14	1	0.14	0.40
B x subject within groups (Error 2)	24.67	18	1.37	
C (motor load)	137.17	3	45.72	242.45+
A x C	0.38	3	0.13	0.67
C x subject within groups (Error 3)	10.18	54	0.19	
B x C	21.68	3	7.23	78.21+
A x B x C	0.18	3	0.06	0.65
B x C x subject within groups (Error 4)	4.99	54	0.09	

+ $p < 0.05$

Chi-square (67.74) was higher than that tabulated (11.40) at $\alpha = 0.05$ (df = 9). This implied that subject-interaction could not be dropped from the ANOVA model. Accordingly, F-ratios were computed. Results of the ANOVA are summarised in Table 4.43. It was found that there was statistically no significant effect of noise ($F < 1$, on response-making speed of humans in the driving configuration employed in the present study. The noise x control position, noise x motor load, and noise x control position x motor load interactions were also found to be non-significant ($F < 1$) for all the interactions). The interaction between control position and motor load, however, was found to statistically significant ($F(3, 54) = 4.0$; $p < 0.05$). This finding necessitated to conduct an evaluation of simple main effects, rather than the overall main effects. Results of this analysis, summarised in Table 4.44, indicated that the variable control-position was significant at all the four levels of the motor load, and motor load was significant under both the control-positions, viz., 'normal' and 'reversed'.

Data were further analysed in terms of response latency values of operators when they manipulated various primary and secondary controls of the vehicle under 'normal' as well as 'reversed' arrangement of controls. Results of this analysis presented in Table 4.45 further confirmed the general pattern of

Table 4.44: Summary of the analysis of simple main effects (Study 4).

Source of variation	SS	df	MS	F
B (control position) at:				
C1 (motor load level 1)	33.43	1	33.43	81.17+
C2 (motor load level 2)	77.67	1	77.67	188.58+
C3 (motor load level 3)	114.72	1	114.72	278.52+
C4 (motor load level 4)	143.07	1	143.07	347.36+
Error Term: ERBC = 0.41				
C (motor load) at:				
B1 (Normal control position)	130.46	3	43.49	941.47+
B2 (Reversed control position)	28.40	3	9.47	204.85+
Error Term: ERCB = 0.05				

+ $p < 0.05$

Table 4.45: Mean RTs (in s) for operating controls at different levels of motor load under normal and reversed control-configurations (Study 4).

Vehicle-controls in Normal (N) and Reversed (R) positions	RT values (in s) Motor Load Levels			
	1	2	3	4
Accel. (N)	2.70	3.61	5.11	6.19
Accel. (R)	3.03	3.85	4.69	5.72
Brake (N)	2.80	3.73	4.69	6.66
Brake (R)	2.99	3.92	4.99	6.55
Clutch (N)	0.00	4.01	5.95	6.84
Clutch (R)	0.00	3.78	4.98	6.15
Gear (N)	0.00	0.00	4.87	5.27
Gear (R)	0.00	0.00	4.48	5.34
Horn (N)	2.93	3.60	3.93	5.21
Horn (R)	2.94	3.60	3.84	5.04

response time variation obtained in the previous studies as reported in Subsections 4.13, 4.23 and 4.33.

To establish relationship between response time of operators and motor load, mean values of response scores pooled over low and high levels of noise were computed as presented in Table 4.46. Based on these mean values of RT, curves of best fit were obtained (Figure 4.41) for normal as well as reversed position of controls through the SCATTERGRAM routine of the SPSS software package (Nie et al., 1975). Response time models were also developed for the two control-configurations of the vehicle. It was found that response time varied linearly with motor load. This pattern emerged for both normal as well as reversed configuration of controls. The RT models were as follows:

For normal control position:

$$t_n = 1.142\,\ell + 1.565 \qquad (4.41)$$

For reversed control configuration:

$$t_r = 0.495\,\ell + 0.240 \qquad (4.42)$$

where, t_n, t_r and ℓ denote their usual meanings. (c.f. Equations 4.11 and 4.12). Various statistics related to these RT models were computed as shown in Table 4.47. It was found that values of R were quite high for 'normal' as well 'reversed' configurations of controls implying thereby a strong linear

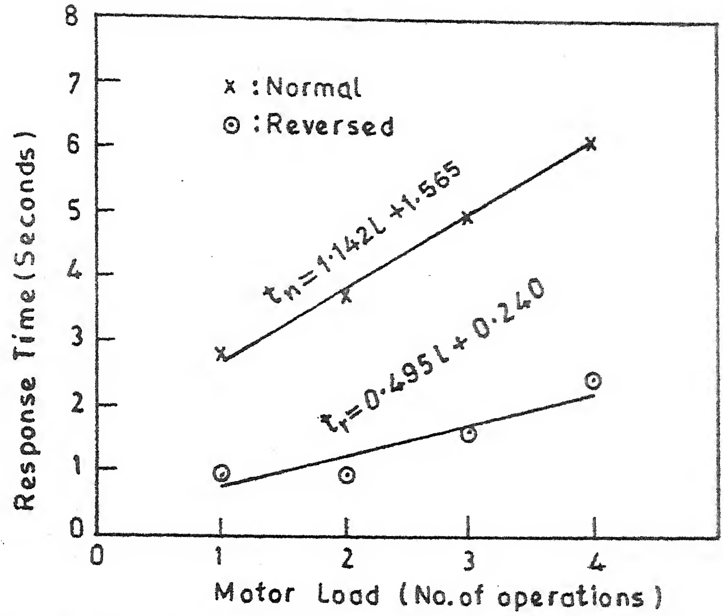

Figure 4·41. Responsetime as a function of motor load for 'normal' and 'reversed' positions of controls (study on noise).

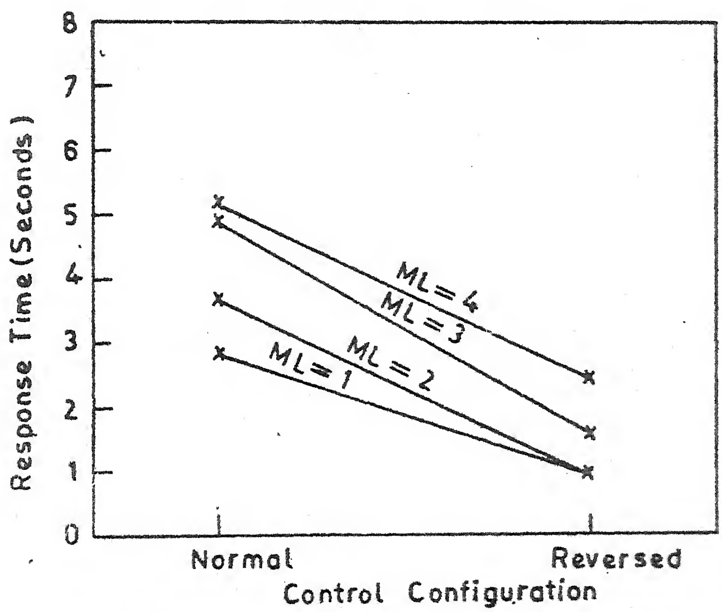

Figure 4·42. Response time under 'normal' and 'reversed' configurations of controls at different levels of motor load (ML) (study on noise).

Table 4.46: Mean RTs (in s) pooled over high and low conditions of noise at different levels of motor load under normal and reversed control-configurations.

Configuration of Controls	RT Scores (in s)			
	Motor Load Levels			
	1	2	3	4
Normal	2.81	3.72	4.97	6.19
Reversed	0.98	0.93	1.59	2.41

Table 4.47: Statistics related to the best fit curves of Figure 4.41.

Control Position	Statistics					
	Corre-lation, R	R-Squa-red	Signifi-cance level	Standard Error of Estimate	Slope (in s)	Inter-cept (in s)
Normal	0.998	0.996	0.002	0.120	1.142	1.565
Reversed	0.926	0.857	0.074	0.320	0.495	0.240

pattern between response time and motor load. The proportion of explained variance as measured by the R-squared value was also found to be quite high. This implied a high degree of predictability of RT from motor load.

Finally, operator's response times were plotted as a function of control-configuration of the vehicle as shown in Figure 4.42. This reflected relative efficiency of the two

configurations of vehicular controls, manipulated by operator's at different levels of motor load.

4.44 Discussion and Conclusions

Results of the present study indicated that the variation in equivalent sound pressure level (ESPL) from 61 dB to 88 dB had no general effect on human performance. It was also found that the presence of acoustic noise does not influence the pattern of interaction between control configuration and motor load. Another finding related to the effect of noise was that there exists no significant interaction between acoustic noise and the two positions of vehicular controls. Same was the case for the interaction between noise and motor load. These findings on the effect of noise corroborate the conclusions drawn by Broadbent (1953, 1957) and Hartley and Carpenter (1974), who studied the effect of noise on performing tasks that were more or less similar to the one employed here. Findings of this study also get support from several other sources (Davies and Hockey, 1966; Foster and Grierson, 1978; Hartley and Williams, 1977; Milosevic, 1983), which have presented similar conclusion i.e. acoustic noise has no effect on human performance. Johansson (1983) studied the effects of low intensity, continuous and intermittent types of noises on human performance. He found no significant main effect of noise on any of the performance tasks. His study,

however, differed from the present study both in terms of task and subjects. Johansson employed the mental performance and writing tasks and used children as subjects of the study. Absence of the main effect of noise in the present study does not verify the general hypotheses derived from the Broadbent's filter and arousal theories (Eysenck, 1982). When viewed in terms of the filter theory it may be suggested that noise appeared to be so soft for the subjects that it got filtered out without appreciably affecting the human performance. In terms of the arousal theory, it appears logical to argue that, in the present study, level of arousal could not be raised by the employed levels of noise beyond what is termed as optimal point of arousal. As a result, it might be suggested that the state of over-arousal could not be reached and hence no deleterious effect of noise could be observed on response-making speed of humans. Another possible explanation for the present finding could be that subjects might be trying to cope with the noise by increasing their level of concentration alongwith the employment of effort, thereby showing no degradation in human performance.

Results of the analysis of response time speed in terms of the 'normal' and 'reversed' positions of controls indicated that at all the four levels of motor load the effect of control-configuration was highly significant. The performance progressively deteriorated as the level of motor load increased from one

to four under the two configurations of controls. Response time, however, was found to be faster for the 'reversed' configuration of controls as compared to the 'normal' one almost at all the levels of motor load. So far as the motor load effect is concerned, it was also found to be significant for both the positions of vehicular controls. Detailed explanations for such findings have already been presented in Subsection 4.14, 4.24 and 4.34 of this Chapter.

An overview of the response latency values for individual controls of the vehicle (Table 4.45) further confirmed that when operators had to respond to more than one control at the same time there was a degradation in their RT speed. Moreover, these latency values also suggested that the 'reversed' arrangement of controls was more efficient than the 'normal' one, particularly, at higher levels of motor load.

Based on the above findings following conclusions are drawn:

1. Within the range investigated, noise does not have a significant effect, on response-making speed of humans in the considered driving configuration.

2. Noise has no effect on humans whether they operate a 'normal' or 'reversed' type of control-configuration.

3. In complex environment of motor loading, 'reversed' configuration of controls is more efficient than the 'normal'.

4. Motor load has a linearly increasing effect on the response making speed of humans.

4.5 Effect of Extraversion - Introversion on Operation Time

The review of literature suggested that one of the most important dimensions of human personality related to individual differences in human performance is the extraversion - introversion (E-I) characteristic in human beings. The present study was planned to investigate if response making speed of humans depends upon this particular trait of personality.

4.51 Purpose

It may be recalled that about 90% of the highway deaths may be traced in terms of human errors in driving, while for the remaining 10% either vehicular or roadway defects are responsible (Loo, 1978). This is an indication of the importance of investigating the effect of driver-related characteristics on the performance of human-vehicle system. One important characteristic of humans, in the context of driving, has been found to be the E-I dimension of personality. Previous researches (Chapter II) have indicated that in a driving task extraverts and introverts are very differently affected under the influence of a stresser (e.g. Zeeman, 1974). It was,

therefore planned to examine the effect of E-I characteristic on human performance in a driving configuration. In light of the above mentioned findings available in the literature, it might be predicted that extraverts and introverts would show distinct patterns of performance. This study aimed at investigating relationship between E-I status and human response-making speed, measured in terms of RT. Another objective of the study was to determine if E-I dimension of personality influenced the driving performance of humans, when they manipulated two different configurations of vehicular controls at varying levels of motor load. Stated in statistical terms, following null hypotheses were tested:

1. Response time of a subject in a driving task is independent of his/her being an extraverted or introverted individual.
2. Human driving performance is not affected by a change in vehicle's control configuration from 'normal' to 'reversed'.
3. In a driving task, varying levels of motor load induce the same amount of stress in human beings, irrespective of their E-I status.

4.52 Method

Twenty subjects who participated in the first xexperiment presented under Subsection 4.1 of this chapter were classified

into extraverted and introverted individuals following the procedure described below.

The E-I inventory (Appendix J) developed by Shanthamani and Hafeez (Pareek and Rao, 1974) was administered to all the 20 subjects. This inventory on E-I contains 20 items, 10 of which relate to extraversion and the remaining 10 to introversion. According to the authors of this inventory, split-half reliability for extraversion and introversion were 0.35 (significant at 0.01 level) and 0.29 (significant at 0.05 level) respectively. Further, the validity measures of 0.72 and 0.82 have been specified for extraversion and introversion respectively.

The above classification of subjects into extraverts and introverts provided a sample of 13 extraverted (6 females and 7 males) and 7 introverted (4 females and 3 males) individuals.

4.53 Results

As in the first study, the analysis of results were carried out in terms of RT only. Mean response time values alongwith their SDs for extraverts and introverts when they performed the experimental task on the vehicle with 'normal' and 'reversed' configurations of controls under the stress of motor load were computed as shown in Appendix K. From the

mean RT values, reproduced in Table 4.51, it may be observed that an increase in motor load results in an increase in response time, irrespective of the E-I status of individuals and control-configuration of the vehicle.

Table 4.51: Mean RTs (in s) of extraverts and introverts at different levels of motor load under normal and reversed control-configurations.

E-I Status	RT values (in s)							
	Normal Control Position				Reversed Control Position			
	1	2	3	4	1	2	3	4
Extraverts	2.07	3.97	5.22	6.31	1.12	0.94	1.68	2.22
Introverts	3.07	4.19	5.77	6.44	0.97	1.05	2.01	2.23

Data related to the two groups of subjects were analysed through a 2 (E - I status) x 2 (control position) x 4 (motor load) factorial design with repeated measures on the last two factors. Since the two groups of subjects consisted of 13 and 7 individuals the unequal group size unweighted means ANOVA was performed (Winer, 1962). Results of the analysis of variance, summarised in Table 4.52, indicate that neither the main effect of E - I nor its interactions with control-configuration, and motor load emerged to be significant ($F < 1$ for all these cases). This implies that the performance of an individual in a driving configuration is not affected by his/her being

an extraverted or an introverted individual. However, the main effect of control position ($F(1, 18) = 4.41$, $p < 0.05$) as well as that of motor load ($F(3, 54) = 2.78$, $p < 0.05$) was found to be statistically significant. Further, the interaction between control position and motor load was also found to be significant ($F(3, 54) = 2.78$; $p < 0.05$).

Table 4.52: Summary of the analysis of variance of RT data (Study 5).

Source of variations	SS	DF	MS	F
Between Subjects				
A (E-I Status)	1.00	1	1.00	0.01
A x subject within groups (Error 1)	1599.59	18	88.87	
Within Subjects				
B (control position)	375.65	1	375.65	53.44+
A x B	0.27	1	0.27	0.04
B x Subject within groups (Error 2)	126.54	18	7.03	
C (motor load)	65.98	3	21.99	16.79+
A x C	0.36	3	0.12	0.09
C x Subject within groups (Error 3)	70.56	54	1.31	
B x C	75.35	3	25.12	5.58+
A x B x C	0.55	3	0.18	0.04
B x C x Subject within groups (Error 4)	242.98	54	4.50	

+ $p < 0.05$

In the next phase of the analysis, relationship between response time of operators (irrespective of their E - I status) and motor load was studied for 'normal' as well as 'reversed' configuration of controls. For this purpose mean RTs were computed as shown in Table 4.53, and curves of best fit were established for the response-making speed of subjects when they operated the two different configurations of controls, viz., 'normal' and 'reversed'. Through the SCATTERGRAM routine of the SPSS software package (Nie et al., 1975) it was found

Table 4.53: Mean RTs (in s) pooled over extraverts and introverts at different levels of motor load under normal and reversed control-configurations.

Position of Control	Response time (in s)			
	Motor Load Level			
	1	2	3	4
Normal	3.00	4.05	5.41	6.36
Reversed	1.07	0.98	1.66	2.22

that for both the control configurations response time of subjects varied linearly with motor load. Following RT models were obtained:

For normal configuration of controls:

$$t_n = 1.144\,\ell + 1.845 \qquad (4.51)$$

For reversed configuration of controls:

$$t_r = 0.413\,\ell + 0.45 \qquad (4.52)$$

where t_n, t_r and θ denote their usual meanings.

Using these RT models, response time functions as presented in Figure 4.51 were obtained. Various statistics related to these RT models (Equations 4.51 and 4.52) were computed as presented in Table 4.54. It was found that values of R

Table 4.54: Statistics related to the best fit curves of Figure 4.51.

Control Position	Statistics					
	Correlation, R	R-Squared	Level of significance	Standard error of estimate	Slope (in s)	Intercept (in s)
Normal	0.998	0.996	0.002	0.119	1.144	1.845
Reversed	0.924	0.854	0.075	0.269	0.413	0.450

(Table 4.54) were very high for both the models of RT, indicating thereby a sound linear relationship between motor load and response time of subjects irrespective of whether they are extraverted or introverted individuals, and irrespective of whether they operate 'normal' or 'reversed' configuration of controls. Moreover, the measures of goodness of fit of RT data to the models as revealed by the obtained values of the R-squared value were also found to be quite high indicating thereby a high strength of association and better predictability of variance between the two variables, namely, response time and

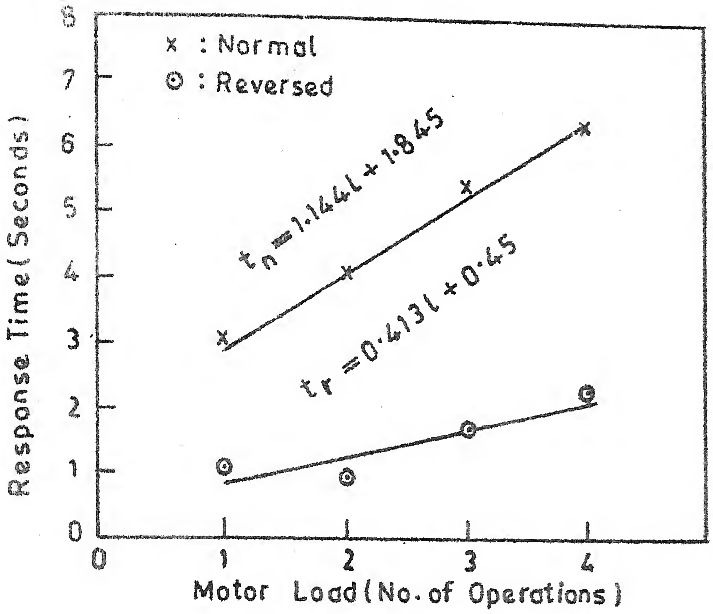

Figure 4·51. Response time as a function of motor load for 'normal' and 'reversed' control positions (study on E-I).

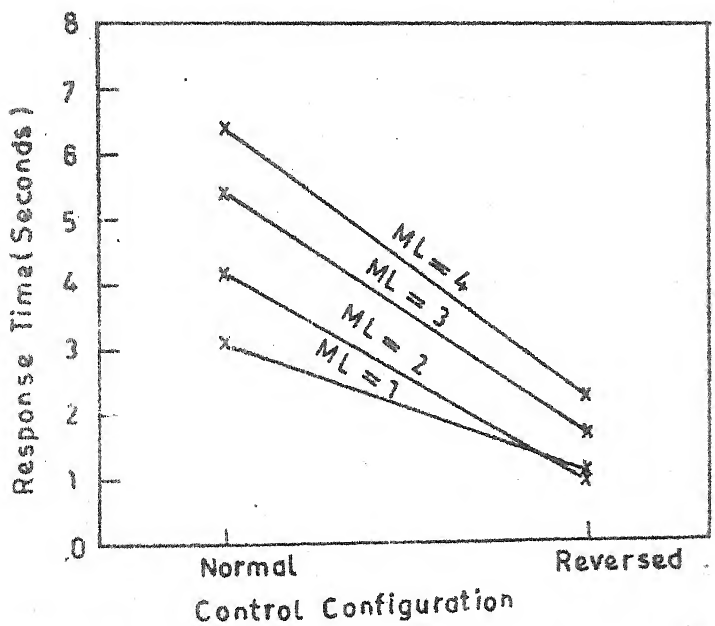

Figure 4·52. Response time under 'normal' and 'reversed' configurations of controls at different levels of motor load (ML) (study on E-I).

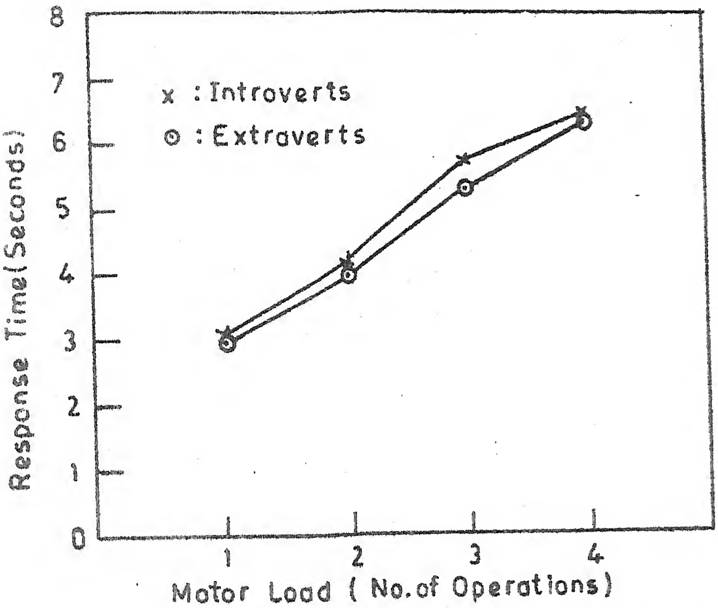

Figure 4·53. Response time as a function of motor load for extraverts and introverts when operating 'normal' configuration of controls (study on E-I).

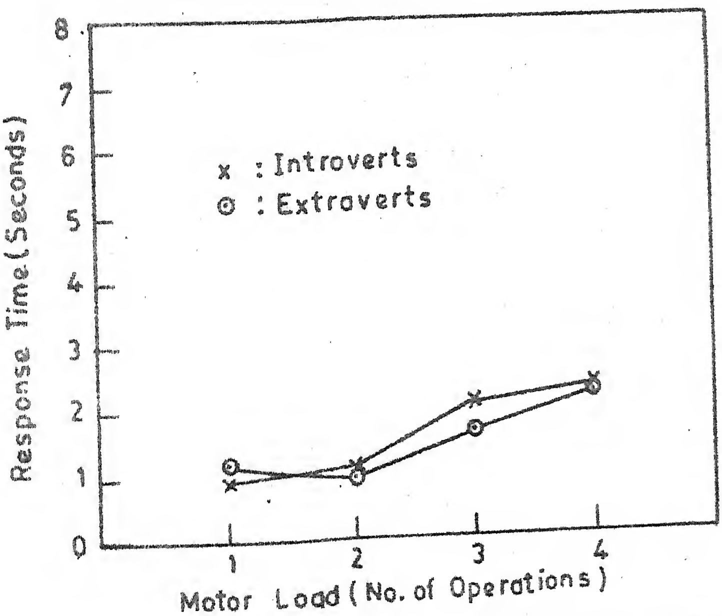

Figure 4·54. Response time as a function of motor load for extraverts and introverts when operating 'reversed' configuration of controls (study on E-I).

motor load. The impact of the control-configurations on human response making speed at each level of motor load is further demonstrated through Figures 4.52, which, in effect reflects the relative efficiency of the two configurations of vehicular controls.

Finally, profiles of RT means are presented for the simple effect of motor load on the performance of the two respective categories of operators, viz., extraverts and introverts when they operated normal (Figure 4.53) and reversed (Figure 4.54) configurations of controls.

4.54 Discussion and Conclusions

Results of the present analysis reveal no significant effect of extraversion - introversion (E - I) status of operators on their response-making speed. Further, the first order interactions of E - I dimension of personality with the control-configuration and motor load were found to be absent. These findings are not surprising in light of the mixed effects of E - I on human performance as reported in the literature. Present results corroborate several other findings related to the E - I characteristic of humans (Fuller, 1978; Schneller and Garske, 1976). Further evidence in favour of the absence of E - I effect on human performance is provided by Gale's review of 16 studies (Gale, 1973) of which six showed no significant difference between extraverted and introverted

individuals. Other studies, however, indicate either introverted or extraverted persons to be superior in performance (Eysenck and Eysenck, 1979; Gale, 1973; Harkins and Geen, 1975; Keister and McLaughin, 1972).

Though the main effect of E - I status did not reach the level of statistical significance, an analysis of the mean RT values (Table 4.51) of the extraverted and introverted people revealed that extraverts possessed an edge over the introverts in responding to the driving task (Figures 4.53 and 4.54). This marginal difference between them, observed under both the configurations of controls, viz., 'normal' and 'reversed', implied that extraverts demonstrate a marginally superior performance to introverts in a driving task. This statistically nonsignificant marginal superiority of extraverts observed in the present study corroborate the findings of Eysenck and Eysenck (1979) who found that introverts were slower than extraverts in the dual task situations. In the learning task of Howarth (1969) also, similar findings were reported. An explanation to this marginal difference between extraverted and introverted people could be put forward in terms of the observation made by Eysenck (1982): 'In general terms extraverts tend to respond faster than introverts under relatively arousing conditions, involving tasks that are intrinsically interesting and/or of relatively short duration'(p. 137).

In light of this, it may be assumed that the little superiority of extraverts observed in the present study might have been possibly because of different degree of arousal caused by the task in the two categories of subjects.

To sum up, following conclusions are drawn from the present study:

1. In a driving task, response-making speed of a person is independent of whether (s)he happens to be an extraverted or introverted individual.

2. Reversed configuration of controls on a two-wheeler offers a more efficient configuration from the ergonomics view point.

3. As the level of motor load increases response making behavior of individuals deteriorates resulting in an impairment in driving performance of humans.

4.6 General Discussion and Conclusions

The five studies presented above provide some important guidelines to the system designers. The present design of two-wheelers in so far as control-configuration is concerned, is equally efficient for all individuals irrespective of their sex (Study 1), motor-sidedness (Study 3), and E - I characteristic (Study 5). The age (Study 2), however, interacts with motor load under the 'normal' configuration of controls.

Noise (Study 4), on the other hand, has no influence on human performance in the considered driving configuration. The main conclusion is that the present configuration of controls on today's two-wheelers does not offer an optimum and most efficient version of control-configuration. However, there are many other salient features, discussed below, that have born out of the present research. The conclusions drawn from these studies equip the human factors engineers so as to come up with a still better ergonomic design of a human-vehicle system.

A consistent finding in all the investigations has appeared in the form of a linear relationship between response time and motor load. It was observed that with an increase in motor load, speed of response retarded. The present set of investigations involved four levels of motor load. Presence of each additional level added to the operational demands made on the subject in the simulated environment of driving. This resulted in an impairment in response-making speed of the subject. Deterioration in performance may be attributed to a fall in reserve capacity of the concerned individual. It is this fall in reserve capacity that in a real life driving situation may result in a hazardous situation on the road (Wetherell, 1981), particularly, under the conditions of increased complexities of the highway and traffic environment.

The extent to which such a deterioration in the driving performance of humans occurs is not only a function of the motor load, but it also depends upon the control-configuration of the vehicle. All of the present investigations have consistently revealed that 'reversed' arrangement of controls is, on the average, more efficient than the 'normal' configuration of controls. The effect of control-configuration is most apparent when performance is observed at the excessive levels of motor load. This is evident from the mean RT values obtained in different experiments and summarised in Table 4.61.

Table 4.61: Summary of the response latency values (in s) obtained in simple (motor load equal to unity) and complex (motor load equal to four) situations of driving under normal (N) and reversed (R) configurations of control.

Driving Situation	Mean Response Latency Values (in s)							
	Normal				Reversed			
	Expt.1	Expt.2	Expt.3	Expt.4	Expt.1	Expt.2	Expt.3	Expt.4
Simple	3.16	3.04	3.16	2.93	3.34	2.99	3.15	3.03
Complex	7.67	7.20	5.99	6.84	5.79	6.03	5.71	6.55

In this table simple situation of driving refers to the one where level of motor load equals unity, while complex situation corresponds to the manipulation of controls at the fourth level of motor load. Based on these values of mean RTs, it may be

concluded that in simple and complex situations of driving, the drivers of two-wheeler type of vehicles should be allowed, on an average, at least 3.1 s and 6.9 s respectively. In case of reversed configuration of controls, the corresponding response latencies of drivers are relatively lesser in magnitude in complex situations of driving, the values being 3.1 s and 6.9 s respectively.

The slope and intercept parameters of the different RT models developed for the 'normal' and 'reversed' positions of controls in the five studies are summarised in Table 4.62.

Table 4.62: Summary of the intercept and slope parameters obtained for the RT models developed for 'normal' and 'reversed' configurations of controls in the five studies presented in Chapter IV.

Parameters of RT	Normal Control Configuration					Reversed Control Configuration				
	St.1	St.2	St.3	St.4	St.5	St.1	St.2	St.3	St.4	St.5
Slope (in s)	1.14	1.138	1.132	1.142	1.144	0.426	0.432	0.384	0.495	0.413
Intercept (in s)	1.85	1.62	1.73	1.57	1.86	0.45	0.36	0.42	0.24	0.45

The intercept parameter of an RT model provides a measure of the efficiency of stimulus encoding and response execution operations (Johnson and Briggs, 1973; Keele, 1973; Smith, 1968), whereas the slope of an RT function is an index of the efficiency

of stimulus identification and response selection processes (Keele, 1973; Smith, 1968). The present findings may partially be understood in terms of these processes. From Table 4.62 it is evident that in case of 'normal' configuration of controls intercept values are consistently higher than the slope values. For 'reversed' position of controls, however, this pattern is not observed in a very consistent manner. In terms of the above mentioned processes, this implies that under normal configuration of controls stimulus encoding and response execution processes take longer than the two processes of stimulus identification and response selection. However, it may be noted that the process of response execution is a motor process, while the processes of stimulus encoding, stimulus identification and response selection are mental processes. It may be assumed that the mental processes are purely a function of stimulus-information and, therefore, they should cause an equal delay under both the configurations of controls. When viewed from this angle, at least the slope values obtained under 'normal' and 'reversed' configurations of controls should have been equal because the slope of an RT function depends purely on mental processes. The results (Table 4.62), however, indicate that not only does a change in configuration of controls affect the intercept, but also the slope of the RT functions. This implies that the process of response selection is not a purely mental activity, rather it might be getting influenced

by the type of the subsequent motor action related to the response(s) to be executed. This suggests that in a decision-taking situation not only do the human beings consider stimulus-related information, but also incorporate the response alternatives in the process of their decision-making.

Difference in the values of intercepts of RT functions under the two configurations of controls may be attributed to a difference in the motor processes involved in manipulation of controls.

The linear behavior of RT functions of motor load, obtained in all the investigations under the two configurations of controls, had a good fit to the RT data. This consistent finding in the present work contradicts the observations made by Julliano (1980), who found no main effect of the memory loading, concluding thereby that humans could process two items in memory as fast as six items. The stimulus material used by Julliano remained confined to faces and pictures which he claimed to be representative of visuospatial and verbal sets of stimuli. The disparity in the present finding and that of Julliano can be traced in terms of differences in the nature of task and the sets of stimuli employed in the two investigations. The results of Boykin's study (1977), however, fully support the present finding. The study conducted by Boykin involved a problem-solving task and, thus, was different

from the one employed in the present research. His results, however, indicated that level of task-complexity had a significant effect on human performance.

To get further insight into the response behavior of subjects, parameters of the RT functions may further be analysed in terms of the estimates of dynamic processing capacities of the individuals. This capacity is usually measured by the processing rate of motor load, and is estimated from the reciprocal of the slope of the RT function (Salthouse, 1982). For the present data, the average estimate of subject's dynamic processing capacity under normal configuration of controls was much smaller (0.88 per s) than that under reversed position of controls (2.34 per s). The difference in capacities under the two configurations of controls was statistically significant ($A = 0.20$, $df = 4$, $p < 0.001$) as revealed by Sandler's A test (Sandler, 1955). This implies that reversed configuration of controls offers a more economical solution in terms of the number of operations carried out in one second duration.

The present findings may also be understood in terms of the time-sharing ability of humans. Driving efficiency of human beings is a function of their perceptual system, decision-making skill, and response-making behavior, and all of these depend upon level of motor load, stressing the individual. All the investigations carried out in this work have consistently

indicated that irrespective of the type of control, slower response rates result at higher levels of motor load. Similar findings have been reported by Damos (1978), who found that with the increasing level of information, response times of his subjects got slower and slower. It could reasonably be expected that existence of time sharing skill would be elicited under the conditions of task interference, which would be reflected in an impairment of the overall performance of the concerned individual. This possibility may be applicable to the present findings if the performance of the subjects is understood in terms of the following possible strategies, they might have adopted while carrying out the experimental task: (1) viewing the contents of a slide, storing them in the memory and then recalling them one by one to manipulate the required controls of the vehicle, (2) viewing the contents of the slide, one at a time, and carrying out the related operation, the process being repeated till all the required controls have been operated, (3) this strategy could be a combination of the above two strategies.

Response time distributions obtained in the various studies rule out the second strategy as response times for individual operations add to more than that for all the operations taken together. Thus subjects might have adopted either the first or the third strategy. Similar explanations

in terms of strategies adopted by individuals in carrying out the experimental task are available in the literature on time sharing ability of humans (e.g. Demos, et al., 1983).

Based on the findings of the studies presented in this chapter, following general conclusions may be drawn:

1. Such organismic and environmental factors as sex (Study 1), motor-sidedness (Study 3), extraversion-introversion dimension of personality (Study 5), and acoustic noise (Study 4) do not influence the response making speed of individuals. This holds for their main effects as well as their interactions with control configuration and motor load. The variable age, however, does have an effect on human driving, particularly at the excessive level of motor load (Study 2).

2. Reversed configuration of controls appears to be more efficient than the normal one. Future designers of the two-wheelers may, therefore, consider in terms of two different control-configurations to bring in compatibility between the vehicle and motor load levels, which drivers are likely to be subjected to.

3. Higher levels of motor load induce proportionately greater stress on humans. A linearly increasing pattern of response time function of motor load emerged from these studies. This finding contributes significantly to the available knowledge

on the amount of load a driver can handle while driving a vehicle. This becomes all the more important when it is noted that there is very little knowledge available on the topic (Gordon, 1981).

Some implications of these findings are presented in the next chapter.

CHAPTER V

SUMMARY, CONCLUSIONS AND SCOPE FOR FURTHER RESEARCH

Driving situation presents a human-machine symbiosis where driver's survival is a function of how (s)he performs in a driving environment. A review of literature related to human driving (Chapter II) indicated several organismic and environmental factors to be of importance in a driving configuration. It was observed that there was ample scope for investigating these factors and, hence, some experimental studies were undertaken (Chapter IV). The general methodology pertaining to these studies is presented in Chapter III. This chapter presents an overview of the findings of these studies. Toward the end, some possible implications of these studies and suggestions for future research are presented.

The five studies presented in Chapter IV emperically investigated the effects of sex (Study 1), age (Study 2), motor sidedness (Study 3), acoustic noise (Study 4) and one of the established dimension of personality, viz., extraversion-introversion (Study 5) on human performance in a two-wheeler driving task. Following major conclusions were drawn on the basis of these studies. First, from the view-point of the ergonomic design of two wheelers, sex and motor sidedness of drivers do

not constitute significant factors of consideration. Second, at a very high level of motor load (i.e. at motor load = 4) response time for high-age operators is significantly higher than that for the low-age operators. Third, acoustic noise, an important factor related to the environment, does not have an effect on human driving performance within the range investigated. Fourth, the fact that an individual happens to be an extravert or an introvert has no bearing on his/her response making speed under the considered driving configurations. Fifth, the reversed configuration of controls on a two-wheeler appears to be a better proposition than the normal position of controls, particularly, at extreme levels of motor load. This finding opens up new avenues in the form of newer problems for human factors engineers in re-evaluating placement of controls on the existing two-wheelers of today. Sixth, increased level of motor loading results in an impairment of human driving performance. Seventh, time-sharing ability appears to be an important skill in a driving environment. Eightth, in terms of response latency values at least 3 s must be reserved for drivers to respond to the road-side environment in simple situations. For complex situations, however, this figure gets somewhat higher depending upon the level of motor load to be handled by drivers; the rate at which the response latency increases depends upon the configuration of controls.

In light of the above findings following observations are made:

1. Reevaluation of existing placement of controls on the two-wheelers is needed. It appears that 'reversed' configuration of controls offers a more efficient version of control-position as compared to the existing 'normal' configuration. Some modifications in the vehicle's current design might result in a more compatible type of man-vehicle system.

2. Time sharing ability appears to be an important skill in driving and, therefore, instead of abondoning this concept as suggested by Damos et al. (1983), it is felt that there is a need for further exploration of this phenomenon with more emphasis on experimental control.

3. It appears that relatively little work has been done in training of higher-age group people on such perceptuo-motor tasks as driving. Licensing bodies would have to come up with tests that identify major problems of elderly drivers. Though the present work, in this context, contributes significantly to the area of performance engineering related to elderly people, yet several issues (e.g. those related to the chronological and functional concepts of age (Salthouse, 1982) from human factors engineering viewpoint) pertaining to the problem remain still unresolved.

4. The finding that noise does not have an effect on human performance and suggestions available in the literature that noise effect on human performance could be detrimental, neutral or beneficial necessitate a more concerted effort on the part of

human factors engineers to explore this issue in a more rigorous manner so as to make the debate on the topic somewhat conclusive.

In the form of scope for future research following suggestions are made:

1. In all of the present studies reaction time was employed as a behavioral measure of human performance. Recently, in neurological literature another measure of human information processing, namely, the force utilised in motor output has been suggested (Virtunski et.al.,1983). In motor-task researches generally encountered by human factors engineers this measure of human performance as a dependent variable might give more insight into the motor performance behavior of humans.

2. Human factors engineering data related to elderly population available in literature are quite inadequate for the human factors engineers to develop appropriate ergonomic design of transportation vehicles (Stoudt, 1981). The study on aging presented in this work has revealed that at extreme levels of motor load high-age subjects are not as efficient in driving performance as the low-age people are. This implies that in complex driving environment involving excessive motor load, age of driver is an important factor. Therefore, it is suggested that more extensive studies on age-related differences should be taken up in future experiments on driving. In this context, learning behavior, time sharing phenomenon and overloading aspects of human performance may be explored.

3. The time-sharing phenomenon needs to be further explored in order to develop an understanding of whether the task-interference involved in performing two tasks simultaneously is due to the competition among the visual organs or it is the result of the time-sharing demand in central processing of the input stimuli. Thus, basically the time-sharing phenomenon could be viewed as a problem of organ-sharing or mind-sharing or a combination of the two. This may have an important relationship with the strategies individuals may follow while driving.

4. The finding that reversed configuration of vehicular controls offers a better proposition than the normal one is based on the results of laboratory experiments. Further investigations on the issue in the dynamic environment of driving should be carried out to provide a sounder footing to the designers of the future human-vehicle systems.

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APPENDIX A

ANNET'S INVENTORY ON MOTOR-SIDEDNESS

FIRST SET

Please indicate which hand you habitually use (or would use) for each of the following activities by writing R (for Right); L (for Left); E (for Either) against each query:

1. To write a letter legibly
2. To throw a ball to hit a target
3. To hold a racket in Tennis or Badminton
4. To hold a match box while striking it with a match stick
5. To hold a broom while sweeping the house floor
6. To cut with scissors
7. To guide a thread through the eye of a needle
8. To deal playing cards
9. To hammer nail on to a wood
10. At the top of a shovel when moving sand
11. To hold the tooth brush while cleaning your mouth
12. To unscrew the lid of a jar

SECOND TEST

Please indicate which foot you habitually use (or would use) for the following activities by writing R (for Right); L (for Left); E (for Either) as above:

1. To kick a ball
2. To pick up a pebble with your toes
3. To step on to a chair (which foot would you place on the chair first)
4. To put on your shoe (which foot would you put a shoe on first)

Sex: Male/Female

Age

Name

Room No.

Hall No.

Volunteer to participate YES/NO

SPECIMEN COPY OF THE OBSERVATION SHEET (INDICATING THE ARRANGEMENT OF SLIDES ALSO) EMPLOYED FOR COLLECTING RT DATA

OBSERVATION SHEET

Subject Code: $MRL_o/MRH_i/FRL_o/FRH_i/MLL_o$

Subject's Name:

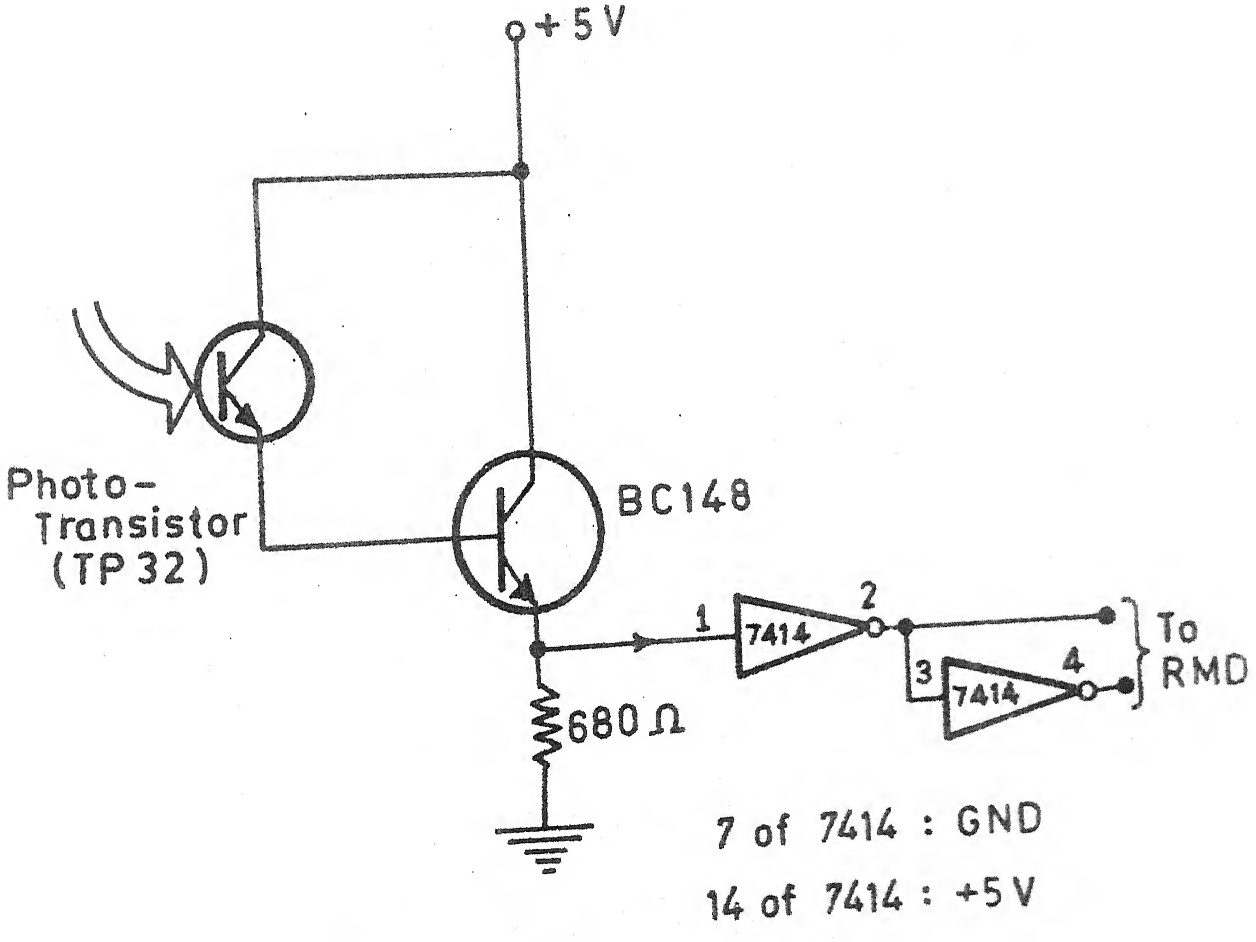
Experiment No.: 1 / 2 / 3 / 4 / 5

Experiment Date: Experiment Time:

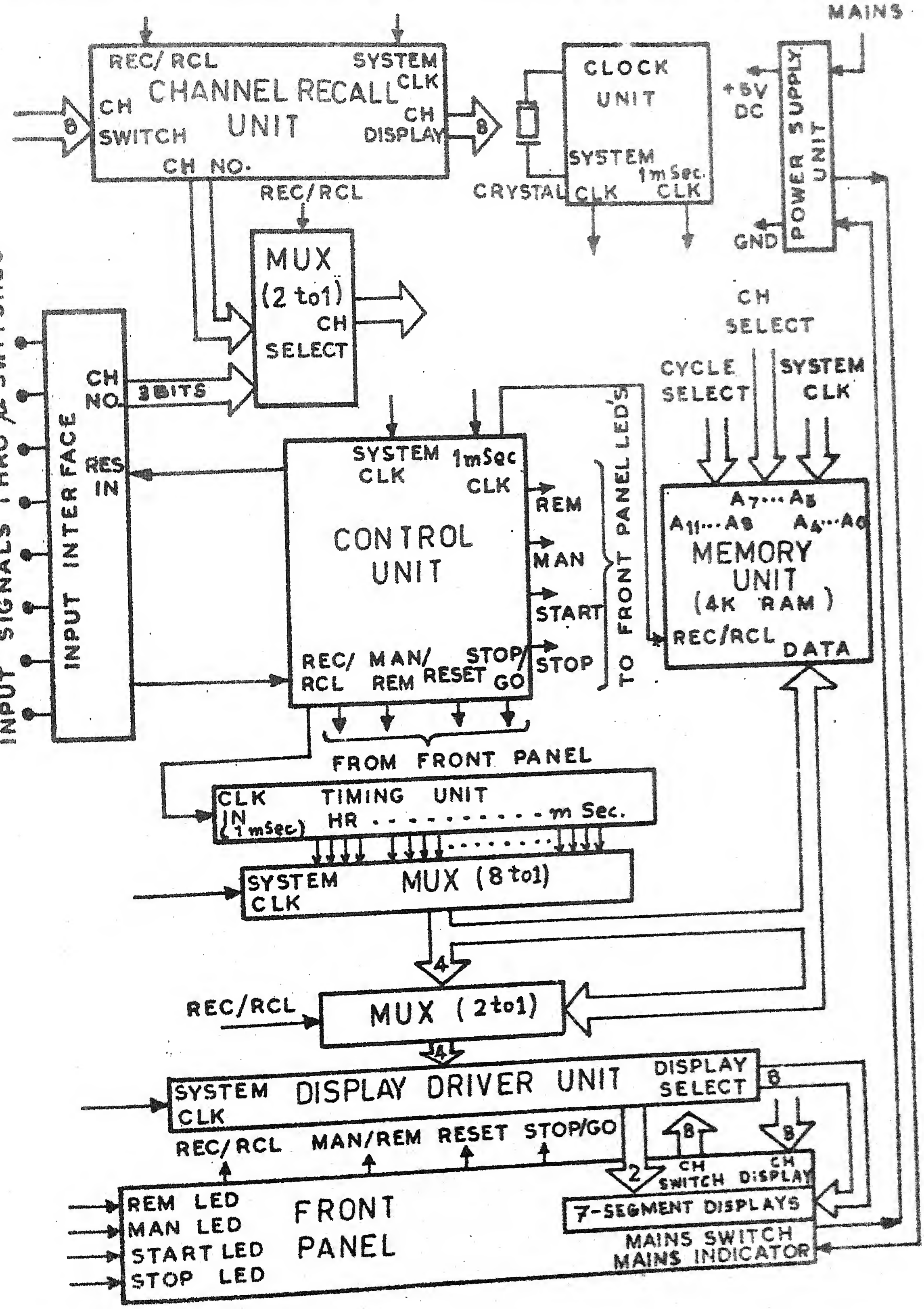
Tymtrak Readings:

Slide No.	Slide Contents	Ch1 h	Ch2 b(Rev)	Ch3 g(Rev)	Ch4 SLIDE	Ch5 b	Ch6 g	Ch7 c	Ch8 a	Remark
1.	a g c .									
2.	h . b .									
3.	c a . b									
4.	h b c g									
5.	. c b g									
6.	a c b h									
7.	c g b a									
8.	. . b .									
9.	g . a c									
10.	. b c a									
11.	b h a .									
12.	. b . h									
13.	b . c .									
14.	. b . .									
15.	. . . b									
16.	. c . b									
17.	a . h .									
18.	h . . .									
19.	. . . a									
20.	a . . .									
21.	h a . c									
22.	. a . .									
23.	h a . b									
24.	. . h .									
25.	b . a .									
26.	b . g c									
27.	. . . h									
28.	b . . .									
29.	c . b .									
30.	c b h .									
31.	. c . b									
32.	. a . b									
33.	h . a .									
34.	. c . a									
35.	g a c b									
36.	. h . .									
37.	. . a .									
38.	b a g c									
39.	. a . c									

APPENDIX C. Photocircuit employed in the instrumentation system.



APPENDIX D. Block diagram of Response Measuring Device (RMD).



APPENDIX E

WRITE-UP PROVIDED TO THE SUBJECTS PRIOR TO THE COMMENCEMENT OF EXPERIMENTATION

INSTRUCTIONS

1. You would be required to sit on the motorbike in which different controls (gear, clutch, brake etc.) have been mechanically and electronically connected to different measuring equipments. While you are on the seat of the vehicle, your two hands should, throughout the experimentation period, be on the handles of the motorbike as is the posture in driving position.

2. During your seating on the vehicle some slides would be projected on the screen, fitted in front of you. These slides contain the following letters:

   a: for accelerator   b: for brake   c: for clutch
   g: for gear   h: for horn

   Different combinations of these letters would also appear on some of the slides. Some of these may contain such irrelevant symbols as □, △ and O. These carry no meanings and, therefore, are to be ignored by you. All the slides have letters and/or symbols arranged as indicated below:

a	b
△	c

△	h
□	O

O	b
h	□

a	h
g	c

   etc

3. As soon as a slide is projected on the screen, you would be required to operate the control/controls as per requirement of the slide, in view.

4. In operating the control/controls you have to be as fast as you can but at the same time please note that the contents of the slide have to be followed as accurately as possible. Thus speed and accuracy both are equally important.

5. In following the contents of the slides you are free to read it in whatever manner you like.

6. For understanding how the operations have to be carried out, you would be given an opportunity to learn the set-up and once you are fully trained, only then actual experiment would start.

7. For any further clarifications, please do not feel hesitated.

APPENDIX F

E - I INVENTORY SHEET

Please answer the questions given below by writing either YES or NO in block presented against the questions. Your responses will be kept strictly confidential and, therefore, kindly answer these questions honestly.

1. I enjoy social gathering or parties
2. My feelings change from happy to sad and sad to happy for no reason.
3. I do not like to be a leader at social functions
4. I can do good work even while people are looking on
5. I like to change from one type of work to another very often.
6. I become conscious of being observed in presence of supervisors
7. I am not afraid of being punished
8. I like to have excitement (i.e. rousing or stimulation) in life
9. My memory is good
10. I worry over possible misfortune
11. I am unhappy most of the time
12. I blush (become red in the face) very often in presence of others
13. I do not have a wide circle of friends
14. One should act on suggestions quickly rather than stopping to think
15. I do not like to keep quite when out in a group
16. Life is for getting pleasure
17. I am not usually calm and collected most of the time.
18. I do not easily get tired of meeting people and talking to them
19. I would prefer to stay at home rather than attend a social function or party
20. I do not like public speaking

Name of the Participant:

APPENDIX G

INDIVIDUAL AND MEAN RT VALUES AND STANDARD DEVIATIONS (IN SECONDS) FOR FEMALE AND MALE OPERATORS PERFORMING THE DRIVING TASK WITH NORMAL AND REVERSED CONTROL CONFIGURATIONS UNDER DIFFERENT LEVELS OF MOTOR LOAD

Sex		Response Time (in Sec.)							
		Normal Control Position				Reversed Control Position			
		Motor Load Level				Motor Load Level			
		1	2	3	4	1	2	3	4
Female	1	2.59	3.03	4.98	5.75	0.80	0.74	1.53	1.77
	2	3.09	4.05	4.83	6.36	0.98	0.89	1.77	2.22
	3	3.07	3.94	4.86	5.92	0.91	0.77	1.38	1.71
	4	3.82	5.51	7.26	9.04	1.17	1.19	2.05	2.95
	5	2.87	4.07	4.74	6.80	0.74	0.70	1.28	1.66
	6	2.73	4.31	6.01	7.32	2.04	0.91	1.71	2.22
	7	2.95	4.74	6.98	4.80	0.94	1.26	2.38	1.77
	8	2.86	4.13	6.74	7.23	1.34	1.10	2.24	3.21
	9.	3.06	4.33	5.46	6.33	1.00	0.87	1.71	2.24
	10	3.19	5.52	7.11	6.29	0.92	1.21	2.43	1.92
Mean		3.02	4.37	5.99	6.58	1.08	0.96	1.85	2.16
S.D.		0.33	0.74	1.05	1.13	0.38	0.21	0.41	0.55
Male	11	3.51	4.52	6.45	8.48	1.06	1.23	2.38	3.23
	12	2.64	3.51	4.83	7.33	1.05	0.82	1.41	2.82
	13	2.33	3.13	4.31	4.09	0.95	0.89	1.35	1.87
	14	2.40	2.85	4.57	4.38	0.84	0.85	1.20	1.42
	15	2.41	3.03	4.05	4.31	0.86	0.81	1.38	1.84
	16	5.20	6.42	8.09	9.59	1.84	1.61	2.99	3.36
	17	2.95	3.43	4.60	5.44	1.01	0.98	1.63	2.44
	18	3.24	3.95	6.42	7.94	1.09	1.07	1.97	2.60
	19	2.45	2.89	4.05	4.92	0.87	0.81	1.29	1.79
	20	2.65	3.33	3.95	4.72	1.01	0.93	1.72	2.34
Mean		2.98	3.72	5.13	6.12	1.06	1.00	1.73	2.29
S.D.		0.87	1.08	1.38	2.02	0.29	0.25	0.57	0.63

APPENDIX H

INDIVIDUAL AND MEAN RT VALUES AND STANDARD DEVIATIONS (IN SECONDS) FOR LOW- AND HIGH-AGE OPERATORS WHEN PERFORMING THE DRIVING TASK WITH DIFFERENT CONTROL POSITIONS UNDER DIFFERENT LEVELS OF MOTOR LOAD.

Age	Subj. S.No.	Response time (in s)							
		Normal Control Position				Reversed Control Position			
		Motor load level				Motor load level			
		1	2	3	4	1	2	3	4
Low	1	2.49	3.76	4.96	6.97	0.94	0.99	1.52	2.35
	2	2.82	3.31	4.60	5.93	1.10	0.82	1.27	2.13
	3	3.00	4.10	6.19	7.27	0.97	1.01	1.96	2.33
	4	2.61	3.05	4.99	4.66	0.87	0.74	1.51	1.78
	5	2.68	3.18	4.51	5.89	0.94	0.76	1.67	1.73
	6	2.04	3.01	4.60	5.63	0.83	0.78	1.61	1.76
	7	3.17	4.46	6.70	9.03	0.95	0.88	1.78	2.11
	8	1.59	2.57	3.48	4.97	0.70	0.75	1.18	1.68
	9	2.95	4.75	5.99	6.92	1.03	0.96	1.61	2.54
	10	3.36	5.28	7.65	9.57	1.23	1.16	2.44	2.78
	MEAN	2.67	3.75	5.36	6.68	0.96	0.89	1.66	2.12
	S.D.	0.53	0.88	1.22	1.62	0.15	0.14	0.36	0.38
High	11	2.26	2.65	3.40	3.79	0.90	0.83	1.26	2.25
	12	2.64	3.42	4.66	5.58	1.36	1.16	1.34	1.92
	13	2.59	2.90	4.28	4.65	0.99	0.91	0.98	2.09
	14	3.05	4.10	5.27	6.09	1.22	1.23	1.91	3.37
	15	3.23	4.12	6.03	7.03	0.95	0.97	1.65	2.58
	16	2.45	2.97	3.31	4.38	0.95	0.92	1.72	1.96
	17	2.58	3.40	4.75	5.59	0.87	0.90	1.52	2.37
	18	3.01	5.27	5.42	6.34	1.00	0.84	1.65	2.26
	19	2.67	2.62	3.97	4.89	1.03	0.81	1.42	1.87
	20	4.93	6.90	6.32	8.13	1.07	1.51	1.62	2.68
	MEAN	2.94	3.84	4.83	5.65	1.03	1.01	1.51	2.34
	S.D.	0.76	1.35	1.06	1.31	0.15	0.23	0.27	0.46

APPENDIX I

INDIVIDUAL AND MEAN RT VALUES AND STANDARD DEVIATIONS (IN SECONDS) FOR RIGHT- AND LEFT-MOTOR SIDED OPERATORS WHEN PERFORMING THE DRIVING TASK WITH DIFFERENT CONTROL POSITIONS UNDER DIFFERENT LEVELS OF MOTOR LOAD.

Motor Sidedness	Subj. S.No.	Response time (in s) Normal Control Position Motor Load Level 1	2	3	4	Reversed Control Position Motor Load Level 1	2	3	4
Right	1	2.31	2.63	3.71	4.50	0.84	0.79	1.35	1.75
	2	3.04	4.04	5.62	7.87	0.95	0.91	1.53	2.06
	3	2.78	3.49	4.56	5.93	0.88	0.79	1.44	1.63
	4	2.52	3.41	5.43	6.10	0.88	1.13	1.59	3.26
	5	2.37	2.61	4.41	6.91	0.89	0.90	1.47	2.01
	6	2.32	3.00	3.99	4.78	0.41	0.47	1.29	1.36
	7	2.95	4.97	6.69	5.70	0.94	0.83	1.24	2.00
	8	3.32	4.63	4.88	6.94	1.24	1.00	1.58	1.96
	9	2.51	2.99	3.71	4.90	0.85	0.73	1.28	1.97
	10	4.79	4.52	4.68	6.38	0.98	0.85	1.52	1.91
	MEAN	2.89	3.63	4.72	6.00	0.89	0.84	1.43	1.99
	S.D.	0.749	0.86	0.92	1.08	0.20	0.17	0.13	0.49
Left	11	3.26	4.66	7.79	8.88	1.17	1.52	2.72	3.07
	12	3.21	4.41	7.32	8,12	1.71	0.96	1.72	2.06
	13	2.57	3.14	4.08	4.42	1.01	1.16	1.34	1.83
	14	2.51	3.28	4.67	5.04	0.95	0.85	1.24	2.11
	15	3.68	4.72	5.36	7.74	1.03	0.97	1.70	2.54
	16	2.50	3.15	4.15	5.05	0.89	0.82	1.40	2.12
	17	2.97	3.84	5.20	4.73	0.80	0.64	1.47	2.11
	18	2.99	3.70	4.82	5.53	1.02	0.66	1.44	1.67
	19	3.19	4.10	6.94	7.67	1.49	0.80	1.66	2.08
	20	3.36	4.13	6.99	7.67	1.49	0.79	1.66	2.10
	MEAN	3.02	3.91	5.73	6.49	1.46	0.92	1.64	2.17
	S.D.	0.39	0.59	1.39	1.67	0.30	0.26	0.42	0.39

APPENDIX J

INDIVIDUAL AND MEAN RT VALUES AND STANDARD DEVIATIONS (IN SECONDS) OF OPERATORS PERFORMING THE DRIVING TASK UNDER LOW- AND HIGH-LEVELS OF NOISE WITH DIFFERENT CONTROL CONFIGURATIONS UNDER DIFFERENT LEVELS OF MOTOR LOAD.

Noise	Subj. S.No.	Response time (in s)							
		Normal Control Position				Reversed Control Position			
		Motor Load Level				Motor Load Level			
		1	2	3	4	1	2	3	4
Low	1	3.56	4.86	6.20	8.95	1.23	1.16	2.44	2.78
	2	2.96	3.88	4.99	6.94	1.22	1.23	1.91	3.37
	3	2.33	2.85	3.94	4.79	0.88	0.79	1.44	1.63
	4	3.20	4.41	5.78	7.16	1.07	1.51	1.62	2.68
	5	3.45	4.98	6.84	9.21	0.88	1.13	1.59	3.26
	6	2.44	2.95	3.78	4.33	0.90	0.83	1.26	2.25
	7	2.55	3.24	4.61	5.80	0.94	0.99	1.52	2.35
	8	2.95	4.09	5.68	6.88	0.97	1.01	1.96	2.33
	9	2.83	3.80	4.92	5.85	1.03	0.96	1.61	2.54
	10	2.38	3.21	4.07	4.58	0.84	0.79	1.35	1.75
	MEAN	2.87	3.82	5.08	6.45	0.99	1.04	1.67	2.50
	S.D.	0.44	0.76	1.03	1.71	0.14	0.23	0.35	0.57
High	1	3.39	4.34	6.89	7.91	0.88	0.78	1.39	2.01
	2	2.95	3.78	4.61	6.49	1.29	0.91	1.68	3.02
	3	1.88	2.84	4.06	5.09	1.43	1.32	2.18	3.38
	4	3.04	4.08	5.22	6.43	0.84	0.82	1.50	2.43
	5	3.67	4.51	6.14	7.27	0.81	0.78	1.25	2.06
	6	2.38	3.08	3.98	4.53	0.81	0.65	1.56	2.28
	7	2.35	3.18	4.49	5.26	0.92	0.76	1.33	1.74
	8	2.69	3.76	4.77	5.97	1.01	0.85	1.67	2.71
	9	2.72	3.45	4.45	5.16	0.78	0.65	1.14	1.48
	10	2.48	3.12	4.06	5.21	0.90	0.75	1.34	2.11
	MEAN	2.76	3.61	4.87	5.93	0.97	0.83	1.60	2.32
	S.D.	0.53	0.57	0.96	1.08	0.22	0.19	0.29	0.58

APPENDIX K

INDIVIDUAL AND MEAN RT VALUES AND STANDARD DEVIATIONS (IN SECONDS) OF EXTRAVERTED AND INTROVERTED (E-I) OPERATORS PERFORMING THE DRIVING TASK WITH NORMAL AND REVERSED POSITIONS OF CONTROLS UNDER DIFFERENT LEVELS OF MOTOR LOAD.

E-I Status	Subj. S.No.	Response time (in s)							
		Normal Control Position				Reversed Control Positic			
		Motor Load Level				Motor Load Level			
		1	2	3	4	1	2	3	4
Extra-verted	1	3.07	3.94	4.86	5.92	0.91	0.77	1.38	1.71
	2	3.82	5.51	7.26	9.04	1.17	1.19	2.05	2.96
	3	2.87	4.07	4.74	6.80	0.74	0.70	1.28	1.56
	4	2.73	4.31	6.01	7.32	2.04	0.91	1.71	2.22
	5	2.86	4.18	6.74	7.23	1.34	1.10	2.24	3.21
	6	3.06	4.38	6.45	6.33	1.00	0.87	1.71	2.24
	7	2.64	3.51	4.83	7.33	1.05	0.82	1.41	2.32
	8	2.38	3.18	4.31	4.09	0.95	0.89	1.35	1.87
	9	2.40	2.85	4.57	4.38	0.84	0.85	1.20	1.42
	10	2.41	3.03	4.05	4.31	0.86	0.81	1.38	1.84
	11	5.20	6.42	8.09	9.59	1.84	1.61	2.99	3.36
	12	2.45	2.89	4.05	4.92	0.87	0.81	1.29	1.79
	13	2.65	3.33	3.95	4.72	1.01	0.93	1.72	2.34
	MEAN	2.97	3.97	5.88	6.81	1.13	0.94	1.67	2.22
	S.D.	0.78	1.05	1.37	1.80	0.39	0.24	0.51	0.62
Intro-verted	14	2.59	3.03	4.98	5.75	0.80	0.74	1.53	1.77
	15	3.51	4.52	6.45	8.48	1.06	1.23	2.38	3.28
	16	3.24	3.95	6.42	7.94	1.09	1.07	1.97	2.50
	17	2.95	3.48	4.60	5.44	1.01	0.98	1.63	2.14
	18	3.19	5.52	7.41	6.29	0.92	1.21	2.43	1.92
	19	3.09	4.06	4.83	6.36	0.98	0.89	1.77	2.22
	20	2.95	4.74	6.98	4.80	0.94	1.26	2.38	1.77
	MEAN	3.07	4.49	5.91	6.44	0.97	1.05	2.01	2.23
	S.D.	0.29	0.83	1.07	1.33	0.10	0.12	0.38	0.53